





1508549 486



UNIVERSITY OF BRISTOL

MEDICAL  
LIBRARY





120 Ed

Bristol Institution

proc. by D<sup>r</sup> Cha<sup>s</sup> Daubeny

Oct. July 1837



*Report published*

*from the Association*

REPORT

ON THE

PRESENT STATE OF OUR KNOWLEDGE

WITH RESPECT TO

MINERAL AND THERMAL WATERS.

BY

CHARLES DAUBENY, M.D., F.R.S., M.R.I.A., &c.

Professor of Chemistry and of Botany, Oxford.

---

[*From the* REPORT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT  
OF SCIENCE *for* 1836.]

---

LONDON:

PRINTED BY RICHARD AND JOHN E. TAYLOR,

RED LION COURT, FLEET STREET.

1837.

1850-1851

1851

1852-1853

1854-1855



# REPORTS

ON

## THE STATE OF SCIENCE.

---

*Report on the Present State of our Knowledge with respect to Mineral and Thermal Waters. By CHARLES DAUBENY, M.D., F.R.S., M.R.I.A., &c., Professor of Chemistry and of Botany, Oxford.*

THE term “Mineral Water,” in its most extended sense, comprises every modification existing in nature of that universally diffused fluid, whether considered with reference to its sensible properties, or its action upon life. For as every agent which affects the animal system in a peculiar manner, must be presumed to possess something in its constitution which is wanting in others, the circumstance of any remarkable medicinal virtue residing in a spring ought, if well established, to be regarded, as a proof of something distinctive in its physical or chemical nature. All medicinal springs therefore will range themselves under the head, either of thermal, or of mineral waters, deriving their properties from the temperature they possess, or from some peculiarity of saline or gaseous impregnation; but the subject-matter of the present Report embraces a much wider field than this, including the consideration of every other description of water, whether circulating through the atmosphere, collected in the ocean, or distributed over the surface of our continents.

The former of these, however, or atmospheric water, as being the purest form of any which nature presents, will supply us with the fewest materials for comment. I ought however to notice the reported detection in it of small quantities, of iron, nickel, manganese, of certain ammoniacal compounds, and of a peculiar organic substance chemically different from the extractive matter and the gluten of plants and animals, which from its yellowish brown colour has been called pyrrhine.

According to the statement of Zimmermann\*, formerly Professor of Chemistry at Giessen, all the above matters are to be found in snow-water, but pyrrhine was first detected in a red shower of rain which fell at that town in 1821. The water that contained it was of a peach red colour, and flakes of a hyacinthine tinge floated on its surface. This latter was the substance designated by the above name.

Some of these results have been since confirmed by Dr. Witting†, of Hoxter on the Weser, who declares, that he has ten times examined the rain-water from his own neighbourhood, and that whilst in seven trials he found it destitute of fixed principles, in three he detected in it foreign matter, which in one case proved to be muriate of potash, and in the other two free muriatic acid. He also found the air collected from elevated spots on the Hartz mountains to contain the same organic principle which Zimmermann had designated as pyrrhine, thus confirming the probability of its existence in rain-water.

He remarked, that the atmosphere of a place contained in general the same foreign ingredients which the first fall of rain brings to the ground, such, for example, as traces of muriates, of free muriatic and carbonic acids, and of carburetted hydrogen gas. Rain which fell during a north-west wind commonly contained much carbonic, together with traces of phosphoric, acid. The latter was discovered on several occasions in rain which had fallen during particular states of the weather; and Dr. Witting goes on to state, that certain plants exhale it, so that when they are confined under glass, traces of this acid may be detected on the internal surface of the latter.

In four out of twelve trials snow was found to exhibit signs of muriatic acid, and of an organic colouring matter. Hail and sleet collected in the spring of 1824 contained a large quantity of this latter substance, but none either of the acids nor the salts above mentioned. Dew showed vestiges of nitric and muriatic acids, but in hoar-frost no signs of any extraneous matter were discoverable.

Upon the whole then it may be observed, that of the above circumstances, the one relating to the existence of organic matter in atmospheric water is best substantiated; and this has more lately been ascribed by the distinguished Ehrenberg to the ova of a particular class of Infusoria (the Polygastrica), which, being raised by currents and by evaporation, fill the atmosphere, and thus produce the pyrrhine observed by chemists‡. The presence of salts and of acids, in the atmosphere, and consequently in water derived from it, is also supported by sufficient evidence.

\* Kastner's *Archiv.*, vol. ii.

† Kastner's *Archiv.*, vol. v.

‡ Ehrenberg in *Jameson's Journal* for 1831, "on Blood-red Water."

Nitric acid, indeed, seems to be spontaneously generated from its elements under certain circumstances as yet but imperfectly understood, as during the decomposition of water by voltaic electricity\*, and in the case of the formation of nitre on walls. We need not, therefore, be astonished to find it sometimes present in atmospheric water. Common salt is also taken up in small quantities by aqueous vapour, and the same is the case with many other alkaline and earthy compounds.

But the existence of metallic bodies in the atmosphere requires further confirmation, although I am not disposed to reject the statements of Zimmermann on this point as altogether unworthy of examination. Faraday indeed has shown†, that such matters cannot be suspended there by the mere repulsive force of heat, since every substance, according to his experiments, possesses a certain fixed point, below which no spontaneous volatilization of its particles takes place, and the limit of volatility in these metals greatly surpasses the highest temperature which the atmosphere ever attains.

Still, however, it becomes a distinct question, whether such bodies may not exist there by virtue of their affinity for others; and experiments recently made in Italy seem to show, that in some manner or other they are so suspended. Thus, Fusinieri‡ has stated, that electrical light carries with it metallic bodies in a state of incandescence, and that ordinary lightning deposits upon the substances with which it comes into contact, sulphur, and iron, in a metallic, as well as in an oxidized, condition. Hence according to him arises the smell which always accompanies thunder, and hence the pulverulent matter deposited round the fractures occasioned in those solid bodies which the lightning traverses.

The connexion of these researches with the origin of meteoric stones is too obvious to require our insisting on; and hence it becomes of the more importance that some fresh experiments and observations should be set on foot, in order that the question may be finally determined.

To conclude my account of the foreign bodies met with in meteoric water, I may mention, that the fact of carburetted hydrogen having been detected in the water of rain, snow, and hail, is the more credible, inasmuch as Boussingault§ has found this same gas in the atmosphere surrounding large cities.

With respect to sea-water, the next modification of this fluid

2ndly. Water of Seas.

\* See Davy's Experiments, 1807, *Philosophical Transactions*.

† *Philosophical Transactions*, vol. cxvi. p. 2.

‡ Becquerel, *Traité d'Electricité*, vol. iii. p. 157.

§ *Annales de Chimie*.



which I shall notice, the only new mineral substances discovered in it are, potash by Dr. Wollaston, iodine by Pfaff, and bromine by Balard. The quantity of the two former is so minute, that the variation of either in different seas still remains undetermined; but the proportion of bromine is considerable enough to admit of being measured with something like precision.

I have myself found it to vary considerably in different samples which I examined.

Thus, 1 gallon of sea-water, taken off Cowes, afforded of bromine 0·915 grain; in the Bay of Naples, 0·925 grain; off the coast near Marseilles, 1·260 grain.

I have since examined two specimens of sea-water taken on the line, the former in long.  $21^{\circ} 30'$  west, the latter in long.  $84^{\circ} 30'$  east, and in both cases detected a larger proportion of bromine than in any of those above mentioned. In one sample, indeed, the quantity indicated was so large, that I suspect some error to have crept into the analysis, and therefore forbear quoting it; in the other, which probably was correct, it amounted to no less than 1·7 grain to the gallon.

I mention these facts merely to stimulate inquiry, deeming them too few to allow of my grounding any inference at present upon them. It may be right however to state, that the quantity of bromine did not depend upon the greater amount of saline matter in some of the specimens than in others, this being found always very nearly to agree.

With respect to the proportions of the latter present in different seas, it has been remarked by Dr. Marcet\*, that the southern ocean contains more salt than the northern, in the ratio of 1·02919 to 1·02757, and that the proportion present in the water at the equator holds the middle place between the two.

This corresponds with my own experiments, which indicated a difference in that respect between the water of the equator taken from long.  $84^{\circ} 30'$  east of Greenwich, and that from the Bay of Naples at a considerable distance from land, off the island of Ischia, about as 100 to 95·5; whilst the water taken from the line, in the Atlantic, in long.  $21^{\circ} 30'$  west, was still salter, being to that obtained in east longitude as 107·5 to 100·0.

This latter result agrees with one of the conclusions deduced by Lenz†, who accompanied Kotzebue in his expedition round the world, from a series of observations made by him during his voyage.

That naturalist ascertained by numerous experiments:

1st. That the Atlantic Ocean is salter than the South Sea, and

\* *Philosophical Transactions*, vol. cxii.

† *Edinburgh Journal of Science*, 1832.

that the Indian Ocean, which unites the two, is saltier on the west where it approaches the Atlantic, than on the east where joins the South Sea.

2nd. That in each of these oceans there exists a maximum point of saltiness towards the north, and another towards the south, the first being further from the equator than the second. The minimum between these two points in the Atlantic is found to be a few degrees south of the equator; in the Pacific it still remains to be determined.

3rd. In the Atlantic the western portion is more salt than the eastern; in the Pacific, the saltiness does not appear to vary.

4th. In proceeding northwards from the point at which the saltiness is at its maximum, the specific gravity of the water diminishes constantly as the latitude increases.

5th. From the equator to  $45^{\circ}$  north latitude, the sea-water, from the surface to the depth of 1000 fathoms, continues uniform in saltiness.

This last conclusion, however, must not be looked upon as fully established, since the instruments, by means of which sea-water has hitherto been drawn from great depths, are considered by the best judges very faulty in their construction, and incapable of affording trustworthy results. Such was the opinion expressed by Dr. Marcet\*, after examining those that had been invented up to the period at which he wrote; and such more recently was the impression of M. Arago†, who hence was led to recommend, to the navigators of the French discovery ship, the *Bonite*, an instrument for the same purpose of M. Biot's invention, which is on a different plan from those hitherto employed.

Instruments for drawing up Water from depths.

The description given of this contrivance by M. Arago is in itself very brief, and is unaccompanied by a plate. Possibly, therefore, I may not have understood every part of its construction, but upon the best consideration I was able to give to the subject, it appeared to me that some parts of the instrument might admit of improvement.

I consequently designed an apparatus framed on a similar principle to that of M. Biot, but provided neither with a spring to exclude the external water, nor with a stopcock and bladder to receive the compressed gas, both which objects were fulfilled by means of a small hollow cap of brass, which being attached to a conical stopper, accurately ground to the hole in the bottom of the instrument through which the water was admitted, dropped down upon this aperture when the vessel was inverted, and thus at the same time would cut off all communication with the

\* *Philosophical Transactions*, 1819.

† *Annuaire*, 1836.



external water, and would receive any air, which upon the removal of the pressure might escape from the body of the vessel.

This instrument has been exhibited at the Mechanical Section, but I am loth to occupy more space in its description, until it has been put to the test of experiment in the open sea\*.

Gases present in Sea-water.

The gaseous contents of sea-water, which with an apparatus of this description may be collected and examined, have not as yet received the attention they appear to deserve.

M. Arago remarks, that oxygen predominates over azote in the surface water both of the sea and of rivers†, and likewise in that of the Mediterranean even at a depth of 1000 metres‡. This latter observation, however, is rendered doubtful by the imperfection of the means hitherto employed for drawing up water from the sea; and supposing it correct, still, as M. Arago remarks, we are left in the dark, as to whether the same law holds good at greater depths.

The determination of this point, however, is of the more importance, inasmuch as some observers have supposed the bubbles of gas, which occasionally rise up through the sea in the vicinity of volcanos, as, for example, off the coast of Sicily, to have been disengaged from sea-water; now these bubbles, unlike what would have been the case, had they been derived from the air existing in the surface-water, were found to contain a predominance of nitrogen gas§. The pressure exercised upon sea-water at great depths would also enable it to hold in solution much larger quantities of air, the presence of which, supposing it to consist in part of carbonic acid, might cause the waters to dissolve a greater amount of carbonate of lime, and thus afford a more abundant supply of that ingredient to the numerous molluscæ, that are building up extensive calcareous formations within the ocean.

Water of Lakes.

Inland seas and lakes may be divided into those which possess an outlet, and those which are destitute of one.

The water of the former commonly corresponds with that of the rivers which flow into them; that of the latter contains in general the same ingredients as sea-water, but in a state of much greater concentration.

\* This apparatus has since been tried off Margate in water of 50 feet in depth, and appeared to answer perfectly.

† The most recent experiments on this subject are those of Dr. Thomson, (*Records of General Science* for Sept. 1836,) who found that the air contained in Clyde water consisted of 70·9 azote, 29·1 oxygen, and that when a mixture of the two gases was placed over water, the oxygen was absorbed much more readily and in larger quantities than the azote.

‡ *Annuaire*, 1836.

§ *Philosophical Transactions*, 1834.

Thus, 500 grains of the water of the lake Ourmia in the province of Azerbaijan in Persia, contains, according to Dr. Marcet, 111 grains of salt\*, and a similar quantity from the Dead Sea 192·5 grains, whereas the largest quantity present in the ocean does not seem to exceed 21·3 grains.

In quality the saline ingredients found in these lakes seem to differ very little from those of sea-water, but Lake Ourmia contained a larger proportion of sulphates, whilst the Dead Sea is found to be entirely destitute of them.

Prof. Henry Rose has lately examined the water of Lake Elton in Asiatic Russia, and has found it to possess a specific gravity of 1·27288, and to contain nearly 30 per cent. of saline matter, which approaches nearly to the quantity present in the Lake Ourmia.

In this, muriate of magnesia was the prevailing ingredient, a circumstance doubtless attributable to the extreme concentration of the solution, which is such as to have brought about a precipitation of the greater part of the less soluble ingredients. Hence rock salt is formed in thick beds, at the bottom and on the sides of this and of several other lakes adjoining the Caspian. The sea or estuary of Ohhotsk, with which are connected the brine springs of Irkoutzk, in Asiatic Russia, contains an ingredient not found in the cases before alluded to, namely, muriate of alumina, with which is associated a large quantity of other deliquescent earthy muriates, ingredients which render the salt obtained from them unwholesome†.

With respect to the borax lakes of Thibet, we possess no information capable of throwing light on the cause of their peculiar mineral impregnation.

Proceeding next to the subject of mineral waters properly so called, I shall notice the circumstances relating, 1st, to their temperature; 2ndly, to their chemical constitution; and 3rdly, to their effects upon the animal economy.

With respect to the first point, much confusion has arisen in the application of the term "*thermal*" to springs. By some, that epithet has been applied to those only, which exceed considerably the average temperature of the springs of the country; by others, to such as reach some arbitrary point in the scale. It appears to me however, that the only precise mode of proceeding will be, to call every spring *thermal* which surpasses ever so little the average temperature of the country in which it is situated; and in constructing a scale of temperatures with regard to them, to calculate it, not by their actual warmth, but by the degree of their excess above the mean of the climate. Thus,

3rdly. Water of Springs.

Their Temperature.

\* *Philosophical Transactions*, 1819.

† *Annales de Chimie*, vol. xli.

a thermal spring having the temperature of  $90^{\circ}$  in this country, ought to stand higher in the scale than one of  $100^{\circ}$  in Mexico, and a spring at  $70^{\circ}$  might justly be termed thermal in the one latitude, but not in the other.

It is on this principle that I have constructed a table, which will appear at the close of this Report, conceiving, that although the exact mean temperature of the locality can in many instances be only guessed at, and in the majority must not be regarded as fully determined, still no error need arise from my mode of expression, as the ascertained temperature of each spring may be readily computed, by simply adding the number which gives the assumed mean temperature of the spot, to that indicating the excess of heat inferred to belong to the spring itself.

Now Prof. Bischof of Bonn\* has remarked, that in almost every case the temperature of mineral springs (amongst which we of course do not include land springs, or waters derived from a superficial source,) is such, as places them, according to the definition just given, amongst thermal ones; and indeed the mere circumstance of a difference in this respect existing among them is in itself a strong presumption that such is the case; for it is evident that, except where a spring has its origin in certain high mountains adjoining, the coldest of the series will approach nearest to the mean temperature of the locality, whilst the remaining ones must derive their excess of warmth from some independent cause.

Thus Bischof examined about twenty springs near the Lake of Laach, and found the temperature of the coldest of them to exceed that of the place by nearly  $2\frac{1}{4}$  degrees of Fahrenheit.

This rule held good even amongst the springs of countries like Hessa, Hanover, Bavaria, and Wurtemberg, where no such decided indications of recent volcanic action exist.

The same remark applies likewise to Artesian wells. Thus the temperature of forty-eight springs bored in and near Vienna, was found by observations made in November 1820, to fall between  $52^{\circ}\cdot 25$  and  $57^{\circ}\cdot 2$ , whereas the mean temperature of Vienna is only  $50^{\circ}\cdot 80$ .

It would be important, if such observations were followed up in other portions of the globe, as well as within the comparatively limited range to which Prof. Bischof's statements apply. In some countries, for instance, where volcanic action has once been rife, as in the Hebrides and in various parts of Scotland and Ireland, one might expect some excess of temperature in the springs of the district over the mean of the climate; whilst in others,

\* *Edinburgh New Philosophical Journal*, April, 1836. It is to be regretted, that a translation of the latter portion of this valuable paper has not yet been published in the above Journal.



where volcanic phenomena are of rare occurrence, as in the Scandinavian Peninsula\*, Russia, and Poland, it would be well to learn, whether the temperature of springs more nearly corresponded with that of the climate, than is the case in the parts of Germany where igneous action may still be suspected. Such an inquiry would not be without its bearing upon those problems concerning the origin of thermal springs in general, which will be discussed in a subsequent part of this Report, for if thermal springs derive their temperature from a remnant of volcanic energy existing beneath, they ought to be most frequent in countries where such energy has at one time or other been manifested; whilst if they simply proceed from a generally diffused heat pervading the interior of our planet, they might be expected to appear in countries of every geological structure.

Independently, however, of the mere question, as to whether there be any evidence of the existence in the springs of a country of an excess of temperature beyond the mean of the climate, and the determination of this question by accurate thermometrical observations both on the air and the spring, neither of which has in most cases been done in a satisfactory manner, two points of inquiry present themselves; first, as to whether there be any periodical variation of heat in the latter from day to day, or at different seasons of the year; and secondly, whether, in the course of the ages that have elapsed since they were first known, any augmentation or diminution of temperature had occurred.

Periodical  
Variations  
of Temperature  
in  
Springs.

Prof. Bischof† has shown, that in some cases the variations of external temperature do manifest themselves in the thermal springs of a district; but this only happens when their excess of heat is inconsiderable.

A similar variation has been observed, as I am informed in a letter with which I was favoured from Mr. Jephson, M.P. for Mallow, in the thermal spring of that town, and it would be desirable that exact observations should elsewhere be instituted on the same point.

A variation of temperature at different periods of the year has been observed in the spring of Bourboule in Auvergne‡, and in that of Balaruc near Montpellier.

Still more important is the question relative to the secular variation of temperature in thermal waters.

In countries where traces of former or present volcanic action are discoverable, and where earthquakes are frequent, the tem-

Secular  
variation of  
Temperature  
in  
Springs.

\* I shall allude to Wahlenberg's observations on this country in a subsequent part of this Report.

† *Edinburgh Journal*, loc. cit.

‡ Lecoq, *Annales Scientifiques de l'Auvergne*.

perature of thermal springs is often inconstant. Thus in Venezuela, Boussingault and Rivero\* found the waters of Mariana  $64^{\circ}$  Cent., whereas Humboldt a few years before determined it to be  $59^{\circ}$ ; and that of Funcheras  $92^{\circ}\cdot 2$ , which Humboldt had found to be  $90^{\circ}\cdot 4$  Cent.

But in the interval between these two observations had occurred the great earthquake, which overwhelmed the Caraccas and other towns situated in the western Cordilleras.

The same explanation however cannot be extended to those thermal springs which are unconnected with volcanic action, and concerning these the testimony is of rather a conflicting nature. Thus Anglada† has compared the temperature of ten springs in the Pyrenees as ascertained by him in 1819, with that determined by Carrere sixty-five years before, and in all of them found a diminution, amounting in one instance to  $27^{\circ}$ , but in the rest varying from half a degree to  $7^{\circ}$  of Fahrenheit. The same observer found an abatement of  $2^{\circ}$  in the spring of Molitg in the eastern Pyrenees after an interval of only two years.

On the other hand, it is remarkable that Berzelius‡ in 1822 found the spring of Carlsbad to possess the identical temperature which belonged to it in 1770, according to the observations of Becher, viz.  $164^{\circ}$  Fahrenheit. Yet so contradictory is the evidence, that this very spring is reported by Klaproth, at a period intermediate between the above two observations, as being  $8^{\circ}$  of temperature lower.

With regard indeed to thermal springs in general, it must, I believe, be admitted, that no observations have been yet made with thermometers of sufficient exactness to set the question at rest; and I therefore conceive, that a valuable legacy has been bequeathed to science by Prof. Forbes in the report on the temperature of the thermal springs of the Pyrenees and others, which he has lately laid before the Royal Society of London, were it only for the pains he had previously taken in verifying, and in comparing with an uniform standard, the instruments he employed.

In the absence, however, of direct experiments, we may be authorized on general grounds to presume, that the temperature of thermal springs, in countries not exposed to present volcanic operations, undergoes no sensible change during a long period of time.

If any change did take place, it would probably be from a higher to a lower degree, rather than the reverse; and as several of the thermal springs which were known and resorted to by the

\* *Annales de Chimie*, t. xxiii. p. 274.

† *Mémoires sur les Eaux Minérales*, 1827, p. 65.

‡ *Annales de Chimie*, t. xxviii.



ancients, such as Aix, Mont Dor\*, Plombieres, and Bath, retain at present a heat as great as is tolerable to the human body, it seems evident, that if they had been only in a slight degree hotter in the time of the Romans, they would have required to be cooled down by artificial means before they were employed for bathing, which we are not told was ever the case.

The same question, as the one concerning the temperature of mineral springs just discussed, may also be started with respect to the quality and quantity of their ingredients. But before we proceed to state what is known on this subject, it will be convenient to advert to a notion at one time advanced by Döbereiner†, namely, that the salts present in mineral waters bear a certain relation as to quantity one to the other.

Fixed Ingredients of mineral Springs.

Ignorant as we are of the processes by which saline substances are formed in the interior of the earth, it might be rash to affirm, that in a mineral water which had obtained its fixed ingredients exclusively from one spot, some fixed ratio did not obtain between the respective quantities of the latter.

Whether in definite proportions one to the other.

But it is inconceivable, that a spring, having to pass through a great extent of rock before it reaches the surface, should not more commonly find certain substances to dissolve, or become intermixed with other currents of water in its way, and that in the event of either of these things happening, the relative proportions of the original ingredients should remain as before.

If, therefore, Döbereiner were admitted to have established, that in a few special cases‡ the salts existing in a mineral water hold a certain definite proportion one to the other, probability suggests, that the circumstance is to be regarded as an exception merely, and not as the rule, and this inference, I believe, will be fully confirmed, by referring to the actual results of the analysis of mineral springs in general.

Hence, without embarrassing ourselves with the consideration,

Whether the Constitution

\* At Mont Dor the very bath exists which was constructed in the time of Cæsar.

† *Ueber die chemische Constitution der Mineralwasser.* Jena, 1821.

‡ I confess myself unable to find any examples which establish Döbereiner's rule. Let us take the Carlsbad water, to which he appeals, and suppose the ingredients to be in atomic proportions. The following appear to be the nearest approximation that can be made :

				Real amount being
Sulphate of soda	.....	15 atoms	$\times 72 = 1290$	— 1290
Muriate of soda	.....	9 —	$\times 69 = 621$	— 517
Carbonate of soda	.....	12 —	$\times 54 = 648$	— 630
Carbonate of lime	.....	13 —	$\times 50 = 650$	— 650
Carbonate of magnesia	..	2 —	$\times 42 = 84$	— 86

Here are some remarkable coincidences, it is true, but how are the proportions of the minor ingredients to be reconciled to such a formula ?

tuents of  
Mineral  
Waters vary  
from time  
to time.

how far such a law as that hinted at by Döbereiner could be reconciled with the idea of a gradual diminution taking place in the strength of the saline impregnation of a spring (which, according to this view, ought to proceed, if at all, in regular proportions likewise), let us simply consider the weight of evidence in favour or against the permanency of mineral springs in this respect.

Cases in  
which they  
have been  
observed to  
be constant.

On the one hand, Bischof\* states, that the mineral contents of the spring of Geilnau in the Taunus mountains, as determined by himself in 1826, agree in quantity with those existing there thirty-three years before, if we believe the report of Amburger.

According to the same author, seventy-seven years have made no difference in the mineral impregnation of the spring of Faehingen in the same district, and the analysis of the water of Selters made thirty-eight years before by Westrumb corresponds very nearly with his own.

Berzelius too has shown, that the composition of the Carlsbad waters accords with the results of the analysis of Klaproth made thirty-three years previously.

Cases in  
which they  
are found to  
vary.

But, on the other hand, the Steinbad at Toeplitz contains, according to the last chemist, scarcely half the quantity of fixed ingredients which were present in it, according to Ambrozzi, thirty-three years before, and even then it was suspected that a diminution from an antecedent period in its saline contents had taken place.

Wurzer† found the spring of Neundorf, in the wet summer of 1833, more fully impregnated with saline matter and with sulphuretted hydrogen, than in the dry summer of 1814.

Klaproth detected in 1806 carbonate of soda, carbonate of magnesia, and silica in the mineral water of Riepoldsau. Sultzer in 1811 could not discover in it one of the above ingredients.

Westrumb in 1788 concluded, that in the Pyrmont water the saline matter was almost constant in quantity, being from 23 to 24 grains in the pint, but that the proportion of the respective ingredients varied. In March 1788 it contained rather more alkaline salt, and rather less gypsum, than in June, July, and August; but though the proportions of the respective salts might vary, the same principles always existed in it.

Struve‡ remarks, that almost every new analysis of the spring of Marienbad affords different results as to quantity, though the total amount of saline matter, and the nature of the acids and bases present, appear invariable.

\* *Vulk. Min. Quellen*, p. 329.

† See Bischof, p. 331.

‡ *Kunstlichen Min. Wasser*, p. 15.

Hermann \* shows, that in the brine springs of Halle the quantity of muriate of magnesia has gone on progressively increasing, and that of the muriate of lime diminishing, since 1798, whilst in those of Schönbeck the sulphate of soda each year has undergone a diminution.

With respect to our own mineral waters, there is a general impression, that the aperient springs, which rise so abundantly from the lias, become weaker when long drawn upon, and it is only in this way that I can reconcile the extreme discrepancy between the analyses of the same spring, at periods not very remote one from the other.

Bischof remarks, that in some cases different results may have been obtained, owing to some variation in the circumstances under which the water had been drawn.

Mode of accounting for this variation.

Supposing the well to have been just before exhausted, the water obtained ought not to be expected to be so strongly impregnated as in common, because time had not been allowed for that which had flowed in since to obtain its full complement of saline ingredients.

In this way he accounts for a discrepancy, between the quantity of sulphate and of muriate of soda, which he detected at Roisdorf in September 1824, and in April 1825; and on the same principle we may explain, why the Pymont water was found to be more strongly impregnated before the season of taking the waters, in May, than during June and July, the months of fashionable resort.

I may add, that if we suppose the respective salts to require different times for their solution, it may be seen, why in some cases the relative proportions of the saline ingredients have appeared to vary, whilst the total amount continued as before; for if, owing to the well having been just before much drawn upon, the salts which required the longest time for their solution existed in the water in a smaller proportion than usual, that very circumstance might enable the water to dissolve a larger quantity of the remaining ones, so as to make good the deficiency, and to render the total amount of fixed ingredients nearly the same as usual.

Considering, therefore, the great uncertainty that exists with regard to this point in most cases, and the progressive condition of chemical analysis, which renders the results obtained at one period scarcely capable of accurate comparison with those of a succeeding one, it were to be wished, that at each of the more important mineral springs samples of the water were preserved in bottles, hermetically, or at least very closely, sealed, to be

Method of determining this question.

\* Bischof, p. 334.



opened at the expiration of a certain time, in order that an analysis should be made of it, as well as of the water fresh taken from the spring, by some chemist of reputation; which being done, and the results being duly registered, a similar sample of the water might be set apart for examination after the lapse of an equal interval of time.

If this method were adopted, the question at issue might soon be determined beyond the possibility of doubt.

Classifica-  
tion of Mi-  
neral Wa-  
ters.

Writers on mineral waters have frequently attempted to classify them according to the nature of their ingredients, but these unfortunately are so often found intermixed in all conceivable proportions, that no division of them into orders founded on such a principle can be regarded as unexceptionable.

For medical purposes the most useful method would seem to be, to select, as the groundwork of the classification, those substances which stamp upon a mineral water its peculiar value as a therapeutie agent, without regarding whether they are predominant in quantity or not. Thus, as the most general division, we might distinguish them into, first, alkaline or carbonated springs, containing a certain proportion of carbonate of soda; secondly, saline, rich in muriatic salts; thirdly, aperient, containing the soluble sulphates; fourthly, sulphureous, containing sulphuretted hydrogen.

The alkaline might then be subdivided into those with, and without iron; the saline into those with, and without iodine and bromine; the aperient into those containing the alkaline, the magnesian, and the aluminous sulphates; the sulphureous into those with *free* sulphuretted hydrogen, or with the hydrosulphurets. Each of their subdivisions might then be distinguished into two sub-orders, the thermal and cold.

Such a classification might be convenient in a medical treatise, but in a scientific one we should frequently find ourselves embarrassed in assigning a place to a spring, which, like those of the Pyrenees, partook strongly of the character of the alkaline class, whilst it was at the same time sulphureous; like that of Wiesbaden, whilst allied to the alkaline ones in its vicinity, was itself strongly saline; or like the Carlsbad, Toeplitz, Bath, and Ems waters, seemed from its mineral constitution to possess an equal claim to admission into several of the classes established.

Ingredients  
found in  
Mineral  
Waters.

With respect to the particular ingredients which mineral waters contain, it would seem superfluous to notice in the present Report any, but those which have been either discovered, or newly investigated, within a short period.

Iron with  
Silica.

Iron in a new form of combination has been detected in the

springs of Lueca by Sir H. Davy\*; the body combined with it being, not the carbonic or sulphuric acid, but silica.

Sir Humphry suggests, that the ochreous deposit so frequent in hot springs, as at Mont Dor, Bath, &c., may be a similar chemical compound, the iron originally existing in the state of a protoxide, but passing into that of a peroxide upon exposure to air.

Though the iron however is thrown down from the water in this condition, it does not follow that it exists there in the same, since, in proportion as the carbonic acid which had upheld it escaped, the silica present in the water might begin to exert its affinity, and be carried down along with the metal.

Iron has also been found by Dr. Thomson combined with muriatic acid in the mineral water of Mitchill in the parish of Nielston†, near Glasgow, and by Lachmund in the aluminous water of Buckowine in Lower Silesia‡.

Iron with  
Muriatic  
Acid.

Manganese was discovered many years ago by Beecher in the springs of Carlsbad; and recent observations have shown that it is by no means uncommon either in cold or in thermal waters.

Manganese.

Thus it has been found in the chalybeates of Pymont§, Marienbad, Seltzers, and Fachingen; at Luxenil near Paris||; at Adolfsberg in Sweden; and in several springs in Russia. Also in the thermal waters of Carlsbad and Ems; the sulphureous ones of Neundorf and Eilsen; the aperient ones of Seidsechutz; and the brine springs of Kreutznach.

It has likewise been met with as a deposit from the thermal water of Popayan in the Andes¶.

Zinc combined with sulphuric acid has been found by Berzelius in small quantities in a mineral water at Ronneby in Sweden\*\*, probably under circumstances similar to those, under which copper is occasionally met with in streams flowing through beds of copper pyrites.

Zinc.

Strontian has been detected in the chalybeates of Seltzer†† and Pymont‡‡, and in the thermal waters of Carlsbad, Konigsworth, Aix la Chapelle, and Borset§§. It seems also to exist in small quantities in the springs of Bristol, it having been found, as I am informed, in a stalagmitical deposit incrusting the pipes that convey water to that city.

Strontian.

\* *Annales de Chimie*, vol. xix. from the "Memoirs of the Academy of Naples."

† *Records of Science*, vol. iii. p. 418.

‡ Bley, *Taschenbuch*.

§ See Bley, *Taschenbuch* for the German springs.

|| *Annales de Chimie*, 1821. ¶ Boussingault, *Annales de Chimie*, 1833.

\*\* Brandes' *Archiv*, b. xiii. as quoted by Osann.

†† Struve, *Künstlich Miner*.

‡‡ Brandes' *Pymonts Heilquellen*.

§§ Bley's *Taschenbuch*.



Barytes.

Traces of barytes have likewise been detected by Brandes and Kruger in the chalybeate of Pymont, and by Berzelius in the thermal water of Carlsbad.

Potassa and Lithia.

Potass was found in that of Toeplitz \* and of Konigsworth in Bohemia; in the water of Bourbon Lancy, by Pavis †; and in one of the Cheltenham waters, by Faraday ‡; whilst even Lithia has been discovered in several, as at Pymont in Westphalia §; at Carlsbad ||, Franzensbad, and Marienbad, in Bohemia; and at Rosheim near Strasburg ¶.

Iodine and Bromine.

The ingredients of salt springs in general have long been understood to be the same, as those which were known to exist in the present ocean, but upon the discovery of the two new principles, iodine and bromine,—iodine abundantly in various marine productions, and more sparingly in the ocean itself; bromine less commonly indeed in the former, but in much larger quantity in the latter,—chemists were naturally led to inquire, whether the correspondence, that had before been traced between the actual and former constitution of these reservoirs of salt water extended also to the presence of the above two bodies in them both. Accordingly Angelini searched for and discovered iodine in certain springs of Piedmont \*\*; Vogel did the same at Heilbrunn in Bavaria ††; and Turner at Bonington near Leith; whilst Boussingault met with it in a spring fifteen leagues from Popayan in the Andes, eighty or ninety miles from the sea, and 10,000 feet above its level ‡‡.

With regard to bromine, this principle was detected by Liebig at Kreutznaach in the Palatinate §§; by Vogel |||| at Rosenheim in Bavaria, and at Wiesbaden in Nassau ¶¶; by Desfosses at Salins, in the Department of the Jura \*\*\*, and at Bourbon les Bains, in France; and by Stromeyer in various springs of the kingdom of Hanover †††.

Having also myself discovered bromine as well as iodine in several salt springs of South Britain, I was led to prosecute an extended examination of the principal ones, containing any con-

\* Berzelius, *Untersuchung*, translated in the *Annales de Chimie*, vol. xxviii.

† *Annales de Chimie*, Nov. 1827.

‡ *Journal of Science*.

§ Brandes and Kruger.

|| Kastner's *Archiv*, b. vi.

¶ *Edinburgh New Philosophical Journal*, for Oct. 1836.

\*\* *Journal des Mines*, vol. viii.

†† *Mineral Quellen des Baiern*, 1825.

‡‡ *Annales de Chimie*, vol. v. 1833, or *Journal of the Royal Institution*, N. S. vol. iii., from Dr. Mill."

§§ *Annales de Chimie* for 1826, p. 330.

|||| *Mineral Quellen des K. Baiern*.

¶¶ Kastner's *Archiv*, vol. xiii.

\*\*\* Ferussac's *Bull.* part viii.

††† See Schweigger's *Journal*, 1827, for "A List of the Localities in which Bromine had been detected."

siderable quantity of common salt, which are distributed through the several rocks of this country, beginning my search with the Silurian formations of Wales, and terminating it with the tertiary deposits of the London basin.

In the tabular view of the constituents of these springs given in the paper I presented to the Royal Society\* on that subject, and which is now published in their *Transactions*, I showed, that although the proportions of the respective ingredients might vary, yet that as regards their quality, an almost entire correspondence must have obtained between the earliest accumulations of salt water and the existing ones, judging from the occasional presence of iodine and bromine in those of all ages.

Thus both these principles were found in waters issuing from the Silurian slates of Llandrindod and Bualt in Radnorshire, and bromine, but not iodine, in those from the coal formation of Ashby de la Zouch, Newcastle-on-Tyne, and Kingswood. Both principles exist in the springs issuing from lias, at Leamington, Gloucester, Tewkesbury, and Cheltenham; whilst in the aperient saline waters of Melksham, Epsom, and London, all of which are connected with newer rocks, iodine appeared to be altogether wanting, though traces of bromine were detected.

It remains to be ascertained by a more extensive induction of particulars than that hitherto made, whether iodine is commonly deficient in springs connected with the more recent deposits; as such a fact, combined with that of its scanty occurrence in our present seas, and its comparative abundance in strata of older date, might lead to some curious geological inferences.

The proportion of iodine to water in different springs, I found to vary from  $\frac{1}{614,400}$  to  $\frac{1}{21,073,900}$  part; and to the chlorine present in it from  $\frac{1}{3140}$  to  $\frac{1}{2,000,000}$  part.

In several of the German springs, however, the proportion appears to be much larger†. Thus, there have been found, in a pint of the salt spring of

	Muriate of Soda.	Muriate of Lime.	Muriate of Mag- nesia.	Hydrio- date of Soda.
Hall .....	10·514	3·356	.....	0·529
Saltzhausen .....	73·450	2·570	8·780	0·590
Kreutznach.....	59·675	11·758	4·124	0·043

In the springs I examined, the proportion of bromine to water varied from  $\frac{1}{9721}$  to  $\frac{1}{153,600}$  part, and to the chlorine from  $\frac{1}{1660}$  to  $\frac{1}{150}$ .

\* *Philosophical Transactions*, 1830.

† Osann, *Ueber Iod- und Brom-haltige Min. Quellen*.

The water however in which I discovered the largest quantity of bromine in proportion to its saline contents was that of Ashby de la Zouch, which contained only 179 grains of solid matter in the pint, and yet yielded more than half a grain of this principle.

This latter result has been confirmed by Dr. Ure in a memoir on these springs published in the *Philosophical Transactions* for 1833.

With respect to the salt springs of Germany, the following proportions of bromine and of other ingredients are contained in a pint of the water of each according to Osann.

	Muriate of Soda.	Muriate of Lime.	Muriate of Mag- nesia.	Hydro- bromate of Mag- nesia.	Hydro- bromate of Soda.
Brine spring of Ragozi at Kissingen	62·050	.....	6·850	0·7000	.....
Pandur ditto....	57·000	.....	5·850	0·6800	.....
Hall.....	10·514	3·356	.....	.....	0·4140
Luhatschowitz ....	18·370	.....	.....	.....	0·0410

The entire absence both of iodine and bromine from a few of the very strongest brine springs we possess, those for example of Droitwich in Worcestershire, as was originally stated by myself, and as has been since confirmed by Dr. Hastings in his Memoir on that subject\*, may be explained by considering, that in these same waters likewise all the more soluble salts present in the sea are of sparing occurrence.

Hence the masses of salt, to which these springs owe their impregnation, may have been the first deposits from the saturated brine, and therefore contain chiefly muriate of soda.

Agreeably with this explanation we find, that the lowest saliferous strata in Cheshire consist of perfectly transparent rock salt, without a trace either of iodine or of bromine, whilst the more deliquescent muriates, together with combinations of these latter principles, are found plentifully in the clays and marls above.

It may at first sight appear doubtful, whether the saline apertures existing in the lias ought to be classed amongst brine springs, considering the larger proportion of alkaline sulphates and of muriate of lime belonging to them.

In a medical point of view clearly they ought not to be so regarded; for their most active, though not always their predominant ingredients, are those very sulphates, which do not exist, except in minute quantity, in brine springs properly so called.

\* *On the Salt Springs of Worcestershire.* Worcester, 1835.



But looking to their origin, or the materials from which they are derived, they must be grouped with salt springs of the common kind, as I have shown in the memoir already quoted.

I may appeal indeed to the authority of Mr. Murchison\* when I state, that these waters, like the genuine brine springs of Cheshire and Worcestershire, rise out of the new red sandstone formation. Hence it is probable, that their original constitution is analogous, but that during the passage of the water upwards through cracks and fissures in the lias clays overlying, the iron pyrites, which is so abundant in that stratum, supplies it by its gradual decomposition with the sulphuric acid found amongst its ingredients.

That sulphuretted hydrogen is generated in the vicinity of these springs, we are assured, not only from the minute quantity of this gas observed in one or two of the Cheltenham and Leamington waters, but also from the strong impregnation of the spring of Willoughby in Warwickshire, as noticed by myself, and of that of Haslar in Worcestershire, reported by Dr. Hastings†.

Now, if we grant the sulphuric acid to be derived from this source, the other differences between these saline aperients, and brine springs properly so called, will admit of an easy solution.

The sulphuric acid, acting upon the several muriates, would form with their bases those earthy and alkaline sulphates on which their medicinal qualities chiefly depend; whilst the free muriatic acid disengaged, attacking the calcareous rocks, would give rise to the production of the increased quantity of muriate of lime present in them.

With respect, therefore, to the origin of the above ingredients modern discovery has added little to the general principle laid down by Pliny, “*Tales sunt aquæ, qualis terra per quam fluunt.*” For it seems needless to attempt tracing them further than the rocks from which the springs themselves issue.

But there are other substances of occasional occurrence that cannot be referred to this source, so immediately, or without a more particular inquiry into the circumstances of their appearance.

Of this description are two acids discovered recently in mineral waters, namely, the phosphoric, and the fluoric, an addition to our knowledge for which we are indebted to the analytical skill of Berzelius. Subsequently, the former substance has

Phosphoric  
and Fluoric  
Acids.

\* *Proceedings of the Geological Society*, vol. i. p. 390.

† *Salt Springs of Worcestershire*, p. 9.

been detected in the following springs amongst others, viz. the chalybeate of Hofgcismar by Wurzer, that of Pyrmont by Brandes, and that of Selters by Gustavus Bischoff; and the latter principle at Carlsbad, Selters, Ems, Wiesbaden, and Gastein.

Now though phosphoric acid is not generally stated as a constituent of the rocks through which these springs have to pass, yet I am inclined to believe, that it exists in minute proportions in very many of those that contain organic remains.

I have myself found traces of it in several secondary limestones; and its existence there may be ascribed, not merely to the coprolites which these strata sometimes envelop, and which are found more or less in formations, even as high in the series as the Silurian rocks of this country, but likewise to the bones of animals, the coverings of crustacea, and the scales of fishes \* distributed through them.

In granitic rocks its presence is equally implied by the occurrence of minerals in which it constitutes the acidifying principle.

The fluoric acid exists in the teeth of animals, but it would be absurd to attribute an organic source to its presence in the strata. Its origin must be looked for in the minerals which the primary crystalline rocks contain. Thus mica and amphibole have been shown by Bonsdorff often to contain small portions of this acid †, and fluuate of lime is to be met with occasionally both in primary and secondary formations.

Carbonate  
of Soda.

There is a class of springs, very common in some countries, though scarcely found in England, which owes its peculiar properties to the presence of a portion of soda, often associated with protoxide of iron, both of which are held in combination by carbonic acid.

Now as carbonate of soda does not exist in any of the strata with which we are acquainted, its occurrence cannot be so immediately referred to the latter; and yet the quantity drawn from the bowels of the earth by the agency of springs must be very considerable, for Gilbert ‡ calculates, that the water given out in a single year by the Carlsbad waters alone contains more than thirteen million pounds of carbonate of soda, and about twenty million pounds of its sulphate, so that we may fairly reckon the annual amount of alkali extracted, under one or the other of these forms, to be as much as 6,746,050 pounds.

\* See Notice of Mr. Connell's Paper in the *Fifth Report of the British Association*, p. 41.

† *Edinburgh Philosophical Journal*, vol. iv.

‡ *Annalen*, vol. lxxiv, p. 198.



But it has been observed, that mineral waters of this description occur in many instances in connexion with felspathic rocks, issuing either from primary strata, or else from volcanic materials.

Now common felspar\* consists, according to Dr. Thomson, (*Outlines of Mineralogy*, 1836, vol. i. p. 295,) of one atom of trisilicate of potass, united to three atoms of trisilicate of alumina; glassy felspar of one atom of trisilicate of potass and soda, to four of trisilicate of alumina; whilst in albite, a mineral in which the ingredients are in the same proportions as in common felspar, the potass is altogether replaced by soda.

This latter alkali is therefore commonly traced to the felspathic rocks in contact with these waters; and, without going into the elaborate calculations which Professor Bischof has thought fit to institute†, by way of showing, that a single mountain of moderate dimensions,—the Donnerburg, for example, near Milledschau in the Bohemian Mittelgebirge,—contains soda enough to impregnate the Carlsbad water for the space of 35,394 years, it will be readily granted, that where a spring is in connexion with volcanic or trappean materials, there can be no want of alkali, to supply it for any conceivable length of time with that portion, which is found belonging to its constitution.

But three questions still remain to be determined, before the source of the alkali can be regarded as explained.

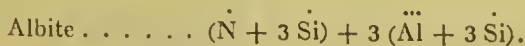
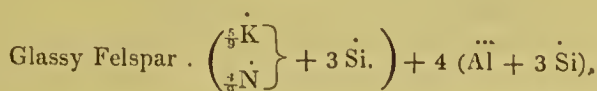
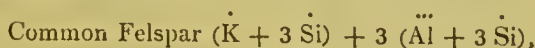
1st. By what process does the thermal water separate this material from its combination?

2ndly. Why does not the same force which extracts the soda, also cause the separation of a portion of the potass, with which granitic rocks at least are still more abundantly charged?

3rdly. How does the spring obtain its soda at all, in cases where it rises, either from granitic rocks containing only common felspar, and therefore no other alkali than potass, or from slates and other rocks that are destitute of alkali altogether?

The first of these difficulties has been elucidated, by the expe-

\* The composition of these minerals may be expressed with greater clearness symbolically, thus:



† *Vulk. Mineral.* p. 322. *et seq.*

riments of Bischof and Struve, and by the observations of Turner.

Bischof has stated\*, that even long-continued boiling in water will separate the alkali from a mass of trass or volcanic tuff, but that the process is facilitated by the presence of carbonic acid; so that he conceives the disintegration of felspathic rocks to be brought about by water impregnated with that ingredient.

Dr. Struve† of Dresden, known for his imitations of some of the most noted mineral springs in Germany, informs us, that he has extracted alkali from granite, by merely filling a tall vessel with small fragments of the stone, pouring upon it distilled water, and suffering a stream of carbonic acid gas to rise slowly through the materials, and to diffuse itself amongst the water filling the interstices between them.

Turner likewise has pointed out the action of carbonic acid and water on such substances in his *Lecture on the Chemistry of Geology*, which will be afterwards adverted to.

With respect to the second difficulty‡, it has been argued, that the majority of these springs arise from volcanic rocks in which glassy felspar predominates; that when they spring from granite, they have been ascertained, in some instances to contain potass as well as soda, as is the case at Carlsbad, and at Schonau near Toeplitz; and in others soda alone, as at Adolfsburg and Porla in Sweden.

It has also been remarked, that granite, in which albite has taken the place of common felspar, is more decomposable than usual§, so that if the water of a thermal spring were to traverse a rock consisting, partly of the one kind of granite, and partly of the other, it might dissolve the soda without affecting the potass.

It has been further suggested by Bischof, that in many of the analyses which have been made, potass may have been mistaken for soda, and that the former is, in fact, a much more common ingredient in mineral waters than has hitherto been suspected.

Bischof also sees a reason for deriving the alkali from the contiguous strata, in the circumstance, that the thermal springs of the Alps, which arise in general from primary rocks, contain little or no carbonate of soda.

To these considerations it may be replied:

1. That the quantity of potass in the Carlsbad springs is too inconsiderable to affect the argument; for it was only by a mi-

Objections  
to this ex-  
planation.

\* P. 305.

† *Ueber Kunst. Min. Quellen*, vol. ii.

‡ See these arguments detailed in full in Bischof's Work so often alluded to.

§ Hence sometimes distinguished as "crumbling felspar."

nute examination of the sprudelstein, the deposit from the waters, that Berzelius was able to detect its presence, whilst in the water itself much carbonate of soda, but no potass, was discernible.

2. That the detection of potass in the Swedish mineral waters only increases the difficulty of explaining, why springs, which, like those of Carlsbad, rise also from granite, contain so very small a quantity of the so-called vegetable alkali, whilst they are thus strongly impregnated with the mineral one.

3. That the alkaline springs alluded to ought to be shown to proceed uniformly from a rock containing albite, before any legitimate inference can be deduced from the alleged difference, as to the facility of disintegration, between this and other kinds of granite.

4. That although it is conceivable that one alkali may have been mistaken for the other by the older analysts, it can hardly be suspected that chemists like Berzelius, or even Anglada, could have been guilty of such an error with respect to the springs they had examined.

5. That although none of the thermal springs of the Alps, with the exception of Yverdun, are represented as containing natron, yet *all* of them are fraught with other salts of soda, and some of them with salts of potass, so that probably the earthy matter present existed in the water in the state of a muriate or a sulphate, whilst the carbonic acid, together with which they were thrown down on boiling, was united in the water with a portion of that soda, which the analyst represents as being combined with some other acid.

Thus the composition of the water of Baden, in the canton of Argau, is stated by Bauhof as follows :

In 300 ounces of the water,

Carbonic acid . . . . .	48 cubic inches.
Sulphuretted hydrogen . . . .	traces.
Sulphate of lime . . . . .	233 grains.
Muriate of soda . . . . .	186 „
Muriate of magnesia . . . .	51 „
Sulphate of soda . . . . .	48 „
Lime . . . . .	36 „
Sulphate of magnesia . . . .	31 „
Magnesia . . . . .	11 „
Extractive matter . . . . .	3 „
Oxide of iron . . . . .	1 „

Now doubtless Bauhoff here meant to express, that the lime and magnesia were thrown down combined with the car-



bonic acid ; but when we perceive the large proportion of soda indicated by the analysis, it seems quite as probable that these earths existed in the water as muriates or sulphates, and that they were precipitated in the state of carbonates by the carbonate of soda, on concentrating the solution.

The same explanation may be extended to the cases of Schinznach, Weissenburg, Pfeffers, and Loucche amongst the thermal, and to Gurnigel and Engistein amongst the cold carbonated springs ; whilst at Fideris, Tarasp, Luxemburg (in Thurgau), and others, carbonate of soda is stated as abundant.

But the greatest difficulty, as appears to me, is presented by the thermal waters of the Pyrenees, which are for the most part richly impregnated with soda, and yet are derived exclusively from granitic rocks, or others equally destitute of mineral alkali.

Should future observations, directed expressly to these particular points, substantiate the fact of the entire absence of potass from these springs, and that of the scanty presence of soda in the rocks with which they are connected, I apprehend the hypothesis of Bischof, plausible as it may seem, and well as it may suit the case of "volcanic mineral waters," must be abandoned, and the same theory be extended to the carbonate of soda, which we have already applied, to the boracic acid present in the Lagoni of Tuscany, and to the common salt exhaled from the craters of volcanos.

New Theory proposed.

There seems at least no absurdity in supposing, that if, as I shall afterwards attempt to show, thermal springs owe their temperature to steam and gases given out by volcanic processes carried on underneath, the former may carry with it, not only boracic acid, but also soda, which, in its passage upwards, might enter into combination with the muriatic, the sulphuric, the carbonic, or any other acid that was present.

Origin of the Carbonate of Soda in certain secondary rocks.

We need not however resort to any such hypothesis in order to account for the occasional presence of carbonate of soda in secondary strata. In salt lakes which become nearly dry in summer, a portion of natron will often result, either from the decomposition of the muriate of soda by calcareous matter, in consequence, as is supposed, of the operation of the law of Berthollet with respect to the influence of the mass, or, as is more probable, from the conversion of sulphate of soda by organic matter into sulphuret, and the decomposition of the latter by the earthy carbonate. To one or other of these causes we ascribe the natron of Hungary, and perhaps that existing in certain mineral waters of Bavaria, said to be remote from volcanic or trappean rocks.

Soda with-

In the cases hitherto mentioned, the alkali has been supposed



to be united with carbonic acid, and this is stated as being the case in the majority of the mineral springs that contain it. out Carbonic Acid in Springs.

Longchamp\* however asserts, that in certain of the thermal waters of the high Pyrenees, as at Bareges, Canterets, St. Sauveur, and the like, the soda exists in an uncombined form, and that to this must be attributed the peculiar action it exerts upon the cuticle, causing the water to feel soapy and unctuous to those who bathe in it.

Anglada† questions this assertion, on the faith of experiments made by him on some of these waters that had been sent him, (as he says,) carefully corked; but trials of such a description cannot of course be put into competition with others instituted, as those of M. Longchamp appear to have been, on the spot, granting both the individuals to be competent authorities on the point.

I may also state, in confirmation of Longchamp's evidence, that being at Barege some years ago, I tested the water fresh drawn from the well with a solution of baryta, and found no cloudiness to be produced till after it had stood some little time exposed to the air, whilst after the addition of lime-water a still longer period elapsed before any indication of carbonic acid appeared.

The experiment was tried with the same success at St. Sauveur.

Dr. Turner has also stated‡, that the springs of Pinnarkoon and Loorgootha in India, which were examined by him, contain soda uncombined with an acid; and Faraday§ has confirmed the statement of Dr. Black, who long ago reported the soda of the Iceland springs as being in that condition.

Now, as in many of these springs no carbonic acid is present, and as the alkaline salt existing in the rock from which they emerge is not a carbonate, but a silicate, we can better understand the possibility of the soda being found in the condition stated, even if, adopting the theory of Bischof, we refer it to the rock in connexion with the spring; whilst those who lean to the contrary hypothesis, and trace the alkali to the very seat of the volcanic action which causes the high temperature, will be able still more readily to account for its appearance in that form.

Silica appears to be an universal ingredient in thermal springs, and is perhaps present in more minute quantities even in those of all temperatures. Silica, its origin in Springs.

\* *Annales de Chimie*, vol. xxii.

† *Edinb. Journal of Science*, No. xvii. p. 97.

§ *Barrow's Visit to Ireland in 1835*.

† *Mémoires*, p. 302.

Its existence in the epidermis of most monocotyledonous plants proves, that it must be held in solution by the descending sap; and the latter, in whatever way it may be supposed to be elaborated within the texture of the plant, can only obtain its earthy principles from the water which happens to encircle the roots.

How far explained.

On the fact of its solution in water, Turner has lately made some observations in his *Lecture on the Chemistry of Geology*\*.

He has shown, that water must have the property of dissolving silica, by contrasting the chemical composition of felspar with that of the porcelain clay which results from its decomposition.

The former, as he represents it, consists of one atom of trisilicate of potass, with one atom of silicate of alumina, in the proportion of nine of silica to one of alumina; whilst porcelain clay consists of seven atoms of silica to two of alumina, or as three and a half to one†.

Hence water had carried off in some way all the potass, and eight and a half out of twelve proportionals of the silica, leaving *all* the alumina and the remainder of the silica untouched.

Now the solution of the silica may be referred in general to its being exposed, at the moment of its disengagement from its existing combination, to the joint action of water and alkali.

But it seems to admit of question, whether the latter be really essential to the process.

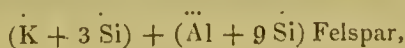
I have myself found a coating of a substance like hyalite in the fissures of a rock in the island of Ischia, through which hot vapours were constantly issuing, and am at a loss to refer it to any other cause, except the gradual solution of silica in the first instance by the steam, and its precipitation afterwards from it.

I have also found, in a soft state, coating fissures in a trachytic rock, near Schemnitz in Hungary, what appeared to be silex hardening into the condition of hyalite, a mineral occurring in many places near,—an observation in which I find myself to be anticipated by M. Beudant.

Dr Wollaston indeed had observed, and Dr. Turner confirms

\* *Phil. Magazine*, 1833, vol. iii. p. 20.

† Represented symbolically thus :



so that  $(\dot{\text{K}} + 3 \dot{\text{Si}}) + 5\frac{1}{2} \dot{\text{Si}}$  have been removed, and only  $3\frac{1}{2} \dot{\text{Si}}$  remain.

the truth of the remark, that steam under high pressure becomes a rapid solvent of alkaline silicates.

The latter chemist even found\*, that glass exposed to the vapour issuing from an high-pressure engine was rapidly corroded, and that the silica taken up was again deposited in a beautiful stalactitical form.

It however remains open to further inquiry—

1st, What is the solvent of silica in springs which contain no free alkali :

How far  
unaccount-  
ed for.

2nd, By what means it is held in solution by the sap of vegetables :

3rd, What are the circumstances which interfere with its solution by artificial means.

With reference to this subject, I may allude to an interesting memoir by Professor Fuchs, on the amorphism of solid bodies†, as throwing some light upon the question as to the solubility of silex, and illustrating the influence in this case of mechanical obstacles upon chemical affinities.

He has shown, that silica exists in minerals in two conditions, a crystallized and an amorphous one, and that in the latter it is much more readily acted upon by solvents, than in the former‡.

Dr. Turner also found, that whilst glass was rapidly dissolved by high-pressure steam, rock crystal remained unchanged.

It would have been curious to determine, whether under such circumstances, amorphous silex (such as opal) would continue untouched.

Muriatic and sulphuric acids in a free state are found only in springs connected with volcanos, to which they are obviously referable.

Muriatic  
and Sul-  
phuric  
Acids.  
Boracic  
Acid.

Boracic acid, which has been detected in a thermal spring of the island of Ischia, and more abundantly in the water of the Lagoni of Tuscany, seems also to be a volcanic product.

It is well known as resulting from volcanic operations in the Lipari Islands and elsewhere ; and its appearance in their craters

\* *Proceedings of the Geol. Soc.*, vol. ii. p. 95.

† *Edinb. New Philos. Journal* for April, 1835.

‡ A recent traveller in Iceland (Krug von Nidda) in Karsten's *Archiv*, vol. ix., remarks, "that the solubility of the silica in such considerable quantity in the hot springs of Iceland, remained for a long time a puzzling phenomenon, until that property was discovered, which it has in common with phosphoric acid, viz. of forming two isomeric modifications, of which one is insoluble in water and in acids ; the other is soluble in both." This may be true ; but the statement must be regarded as a mere expression of a fact, not as the explanation of it.



becomes intelligible, when we reflect, that although dry boracic acid continues fixed at high temperatures, yet when steam is passed over it at a red heat, a portion of the acid is always sublimed, as I have myself ascertained by experiment.

Whether the same explanation will apply to the case of the lakes of Thibet, whence so large a quantity of borate of soda is obtained, future travellers must determine.

#### Nitric Acid.

Nitric acid, united probably with potass (this alkali being found along with it), sometimes occurs in the springs of large towns, as observed by Pagenstecher\* in those of Berne, and by Berzelius in those of Stockholm†.

There is also a tract in Hungary, included betwixt the Carpathians and the river Dran, throughout which all the springs are said to be impregnated with this ingredient‡.

The spontaneous production of nitre, wherever organic matter in a state of decomposition remains in contact with calcareous rocks, or with earth containing carbonate of lime, may sufficiently account for its existence in such springs as these, which probably owe their origin rather to superficial than to deep-seated causes.

It remains, however, to be inquired, whether the same explanation can be extended to the waters of St. Alban, Dep. de Loire§, and of Münchhof|| in Germany, in both of which nitre is said to be present, and that not, as in the former cases, in variable, but in fixed proportions.

#### Ammonia in Springs.

Can we attribute to the same decomposition of organic matter the presence of ammonia in certain mineral waters?

Scherer¶ mentions a sulphureous spring in Courland, which contains it in union with the muriatic acid; and Osann\*\* one at Raab in Hungary; whilst Berzelius†† notices its occurrence in the mineral waters of Porla, united with a peculiar acid, the crenic, which will be noticed presently.

Longchamp also states, that there are traces of it in some of the thermal springs of the Pyrenees; but he does not state in what state of combination it occurs.

Professor Fischer‡‡ of Breslau has detected it in combination with carbonic acid in the thermal water of Warnibrunn, in

\* *Uebersicht der Bestandth. der Brunnen der Stadt Berne.*

† Osann, vol. i. p. 92.

‡ *Ibid.*

§ *Patissier Manuel des Eaux Minérales*, p. 280.

|| Schweigger, *Journal*, vol. xlv.

¶ Page 180.

\*\* Page 85.

†† *Phil. Magazine*, vol. vi. p. 239.

‡‡ Groese, *Jahrbucher für Deutschlands Heilquellen*, 1836.



Silesia; Wetzler\* in the cold spring of Krumbach, in Bavaria; and Kastner† in that of Kissingen, in the same kingdom. The water of Clinton, near New York, is likewise stated to contain five grains of carbonate of ammonia in the gallon‡.

It may, indeed, be suspected that this principle is in reality of still more frequent occurrence, and that chemists have often overlooked its presence, in consequence of having driven it off by the heat which, in analysing the water, they had in the first instance applied.

Now in many of the above instances, I should be disposed to ascribe the occurrence of ammonia to causes of the same description, with those which I suppose to have given rise to it when found issuing from the spiracles of volcanos, especially as it is remarkable that, although the evolution of nitrogen gas and of ammoniacal compounds in a few rare instances occurs simultaneously, yet for the most part the two in a manner take each other's place, the volatile alkali being abundant in active volcanos, where nitrogen gas is not common, and scanty and unfrequent in the thermal springs of primary countries, where nitrogen gas is so generally disengaged.

My own views respecting the formation of ammonia in volcanos are stated in my Memoir on the eruption of Vesuvius in 1834, published in the *Philosophical Transactions*, and will be elsewhere referred to in this Report; but I should be unwilling to extend them beyond the case of those springs which, judging from their temperature, appear connected with volcanic action, and from their purity, or freedom from organic matter, cannot be supposed capable of generating ammonia by any process of animal or vegetable fermentation.

To these latter causes I should of course refer the presence of ammoniacal compounds in those waters, which, from their contiguity to large cities, or from their own impure condition, seem to contain in themselves the elements from which the volatile alkali might be generated.

Whilst speaking of ingredients which may be suspected to arise from the presence of organic matter in springs, I must state, that formic acid is said to have been detected in the waters of Prinzhofen near Staubing§, and at Brunnen near Emkirchen, four or five leagues from Erlangen||, both in Bavaria; and acetic

Formic  
Acid.

Acetic Acid.

\* Kastner's *Archiv*, vol. x.

† Silliman's *Journal*, vol. xviii.

§ Pattenhofer, in Kastner's *Archiv*, vol. vii.

† *Archiv*, vol. xxvi.

|| *Archiv*, vol. xxiii.

acid in a spring at Craveggia in Piedmont, by Vauquelin; and also in those of Ronneberg\*, and Bruchenau in Bavaria.

Crenic and  
Apocrenic  
Acids.

More recently Berzelius has described two new vegetable acids in the springs of Porla† in Sweden, to which he has given the names of the crenic and the apocrenic, both derived from an organic matter present in the water, the crenic first, the apocrenic from the other by the action of oxygen.

Crenic acid does not crystallize, but its solution in water concentrated to the consistence of a syrup is almost colourless. When dried in vacuo it splits in all directions, and its taste is then distinctly acid and astringent. Though a weak acid, it decomposes the acetates, and combines with the alkalis and alkaline earths. Most of them are insoluble in water, but the protocrenate of iron is soluble.

The apocrenic acid imparts a brownish colour to water, in which it is but slightly soluble. Its salts resemble the crenates, but are either brown or black, and are insoluble in alcohol.

They combine with hydrate of alumina when digested with it, and form a colourless solution.

These two acids were found in several chalybeate waters in Sweden, and may be separated from the ochre which they deposit by boiling it with potass.

The crenic acid ‡, or one much resembling it, has since been detected by Professor Fischer of Breslau in the mineral spring of Landeck in Silesia §.

Organic  
matter in  
Springs.  
Glairine, or  
so called  
animal  
matter.

The above acids may possibly have some connexion with an organic substance found in most thermal and many cold springs, which has excited much speculation, and been supposed to possess important medicinal qualities. We owe the first accurate information respecting it to Bayen ||, who, in 1765, published an account of the mineral water of Luchon, in the Pyrenees, in which he discriminated this flocculent matter from the sulphur also present.

In 1786 Dr. Willan ¶ described a white mucous substance existing in the waters of Croft, in the county of Durham, which

\* Döbereiner in Kastner's *Archiv*, vol. xvi.

† *Phil. Magazine*, vol. vi. p. 239.

‡ The crenic acid has lately, it is said, been found to be an ingredient of the Bergmehl of Lapland, which the natives in times of scarcity mix with their flour, considering it to contain nutriment. This material is stated to be chiefly made up of the outer shells of fossil infusoria, together with some animal matter probably derived from their internal substance, and of the acid alluded to.—*Phil. Mag.* for April 1837.

§ *Jahrbucher Deutschlands Heilquellen.*

|| *Opuscules Chimiques.*

¶ *On Croft and Harrogate Waters.* London, 1786.

had likewise been confounded with the sulphur given out by the same springs.

In a recent visit to Croft I found this substance in abundance, and traced it as far as the water flowing from the spring retained its sulphureous odour, but not when the latter was dissipated.

Mr. Dillwyn, in his work on British *Confervæ*\*, notices the same as occurring, not only at Croft, but likewise at Harrogate in Yorkshire, and Llanwrtyd in South Wales, all of them springs of similar composition, and determined the substance to be a *Conferva*, which, from its whiteness, he denominatcd *Nivea*.

In the thermal spring of Bath a *Conferva* of a different species abounds, which, from its colour and appearance, used to be called Bath sulphur, although not a particle of this latter principle exists in these waters.

It seems, therefore, to be generally agreed, that the mucous matter found in the mineral waters of this country is owing to the generation of organized beings; but with respect to that met with amongst thermal and other springs in various parts of the Continent, no such correspondence of opinion subsists.

On the one hand, Bory St. Vincent, in a memoir “*Sur la Botanique des Eaux*†,” appears to attribute it in every instance to the growth of a certain class of *Confervæ*, to which he has given the name of *Anabaina*.

To this opinion also M. Delarive, in his memoir on the springs of St. Gervais‡, adheres; and I am informed by Professor Decandolle, that the waters of Acqui in Piedmont were examined by him with reference to this point, and that he always found himself able to detect in the so-called *animal matter* which abounds there an organic structure.

Many chemists, on the other hand, have taken up a contrary view of this subject, amongst whom I may instance Professor Anglada|| of Montpellier, who, in his elaborate work on the mineral waters of the Eastern Pyrenees, has given a detailed description of its properties, as presented in the localities he has specified.

The substance in question he denominates *glairine*, from its Described. glutinous or jelly-like appearance. It was observed by him in cold as well as hot sulphureous springs, in all nearly fifty in number. It occurs in flocks, in threads, having the character of mucus, or of membrane, in compact concentric coats or

\* P. 54.

† *Bulletin de la Société Philomatique, et Dictionnaire Classique d'Histoire Naturelle*, art. ARTHRODIE.

‡ *Bibliothèque Universelle*, vol. xxii.

|| *Mémoires pour servir*, &c., vol. i.



zones, in parallel fibres, and pendent in a stalactitical form from caverns.

With respect to colour, glairine is of various shades of either white or red, the latter being found generally in the hottest springs.

It gives out a mawkish smell, succeeded after a little time by one of a more repulsive kind, arising from its decomposition. In its chemical properties it bears most resemblance to animal mucus, and disengages azote when acted upon by nitric acid. M. Anglada afterwards shows that the thermal waters which deposit glairine, also contain a portion of the same in a state of chemical combination, the largest quantity, however, present not exceeding one third of a grain to the pint.

As the water cools, a portion of this matter separates, and may then sometimes be perceived floating in it in minute semi-transparent flocks of a mucous character.

Accounted  
for.

It is this latter circumstance, which principally leads him to suppose, that the glairine exists formed in the interior of the earth, and that the mineral water is merely instrumental in bringing it to the surface.

In order to explain how such a product could arise, Anglada appeals to an experiment of Döbereiner's, who found, that when steam was passed through an iron tube containing heated charcoal, a gelatinous matter frequently made its appearance. He also notices the production of a fatty-looking substance by Berard, on passing through a red-hot tube a mixture of carbonic acid, olefiant gas, and simple hydrogen.

It is with great diffidence that I dissent from the views of M. Anglada, who has undoubtedly paid more attention to this remarkable substance than any other individual that could be mentioned, and question the fact which he so confidently affirms, of the occurrence of specimens of glairine in the Pyrenean springs and elsewhere, to which it would be impossible to assign an organic origin†.

\* Vol. xiii. part i.

† In further corroboration of my views I may quote the authority of the naturalist Turpin, who has also examined two specimens of the so-called Baregine, the one from Barege, the other from Neris. An investigation of them under the microscope proved, that chemists had been confounding under the same name, several very different organic products, and that the so-called Baregine from Neris had no resemblance in its origin or constitution to that from Barege.

The former, which he obtained from Robiquet, was nothing else than the *Nosthoc* or *Conferva thermalis*, already so often described. That from Barege, which he got from Longchamp, consisted of a gelatinous transparent and almost colourless substance, without any apparent mark of organiza-



Nevertheless, the observations I have myself made in some of the very same localities as those visited by M. Anglada, the substance of which is given in the *Linnean Transactions*\*, lead me to conclude, that the glairine of M. Anglada is frequently; and therefore justify me in suspecting that it may be always, generated at or near the surface, by the rapid growth of certain lower tribes of organic beings.

At Greoulx I remarked large patches of it hanging from the sides of a highly inclined rock, over which the water of that thermal spring had descended.

Now if it had been a chemical precipitate from the waters, this could not have happened; but supposing it an organic matter, whose growth was favoured by the temperature or the constitution of the spring, its presence therein is not more difficult of explanation, than that of Algæ on the face of a precipitous cliff.

Moreover, the specimens of glairine which I collected always presented under the microscope, in some part or other, an organic structure.

It is indeed true, that I detected traces of what appeared to be the same substance in the water of Barege fresh drawn; but it being admitted that, like many other organic matters, glairine is slightly soluble in water, and more so in hot than in cold, its presence there may be explained, if we only suppose that its growth proceeds, not only in the open air, but likewise in those fissures and cavities underground through which the water has to pass.

Berthier† also, who has considered this subject in a memoir on the Hot Springs of St. Neetaire, declares that he has never found this organic matter in waters taken from the fountain-head, and corked directly afterwards, but that it makes its appearance after a very short exposure of the water to air and light. Though this remark may not be universally true, the larger deposits of glairine, I believe, always arise in water that has been exposed to the atmosphere.

In short, there seems no insurmountable difficulty, in the way of our attributing the existence of glairine everywhere to the growth of organic bodies, such as should reconcile us to the

tion. It is a slimy mass formed out of a great number of parts, which for the most part arose from the decomposition of plants and animals, especially Infusoria.

It is plain from this, how necessary it is that the chemist should ascertain the homogeneous nature of any substance which may be suspected to be organic, before he submits it to chemical analysis.—Poggendorff's *Annalen*, 1836.

\* Vol. xiii. part i.

† *Annales des Mines*, vol. vii. p. 215.

adoption of an hypothesis, so strongly opposed to probability as that advocated by Anglada.

Those who are sceptical as to the possibility of so very rapid and apparently so spontaneous a production of organic matter, as that which takes place in these thermal waters, should peruse a memoir in Schweigger's *Journal*\*, and also one more lately published in Poggendorff's†, by the celebrated Ehrenberg, on the blood-red appearances observed at various periods, covering the surface of lakes and stagnant pools, spreading over various articles of food, or descending in rain from the heavens.

The former of these papers proves the rapidity with which bodies of this kind are generated; the latter establishes, that in almost every case in which the particulars have been carefully investigated, the phænomenon has resulted from the generation of some kind or other of organic matter.

There is, indeed, an observation of Gimbernatt‡, which ought perhaps not to be passed over, although I am not myself disposed to attribute any weight to it. I allude to his finding a substance similar at least to glairine, if not identical with it, in the condensed vapours proceeding from the fumaroles of Vesuvius. But when we recollect, that the apparatus in which this steam was collected had been allowed to remain for one or two days without being disturbed, during which time the water was freely exposed to atmospheric influences, under circumstances peculiarly favourable to the growth of *Confervæ*, there seems no necessity for supposing the organic matter found in it to have been derived from the entrails of the volcano.

I have myself collected, on several occasions, the vapours that arose from the spiracles of this very same mountain, after the great eruption of 1834, as I have stated in the memoir which I published in the *Philosophical Transactions* for 1835, but in no instance could I discover any organic matter.

Red ferru-  
ginous mat-  
ter.

In the thermal springs of Vichy, and in some other localities, where sulphur is not present, an organic substance has been observed floating on the surface§.

Longchamp, in his account of that spring, states that it is intermixed with carbonate of lime, together with which I found entangled within its meshes a portion of peroxide of iron; and

\* For 1827; extracted from a work by Dr. Sette, entitled *Mem. Storica Naturale*. Venezia, 1824.

† Translated in *Edinburgh New Philosophical Journal* for 1830.

‡ *Bibliothèque Universelle*, vol. xi.

§ Vauquelin, *Annales de Chimie*, vol. xxviii.

in the memoir already referred to\*, I explained the mode in which I conceived these substances to find their way to the surface.

It seemed to me probable, that each portion of warm water, from below, as it rose to the surface of the well or reservoir which received the overflowings from the spring, would set at liberty a little of the earthy and ferruginous matter it had held in solution, in consequence of the disengagement of some of the carbonic acid with which it had been surecharged whilst under a greater pressure.

But this solid matter, being entangled in the *Confervæ* floating on the surface, would be prevented from becoming precipitated; and would form, by degrees, an earthy and ochreous crust upon the water.

But Professor Ehrenberg, of Berlin, to whom we are indebted for so many striking discoveries with respect to recent and fossil infusoria, has thrown quite a new light upon this subject, having ascertained, as he lately assured me, that this red matter is in fact composed of the outer sheaths or coverings of a multitude of little infusorial animalcules, which appear to possess the singular property of secreting oxide of iron as well as silica, and hence thrive only in chalybeate waters, which afford them the material for the coat of mail which invests their softer parts. This at least he finds to hold good with respect to the red ferruginous matter which collects in certain chalybeate waters in the neighbourhood of Halle, and I have little doubt that the same will apply to the similar incrustation found in the water of Viehy, &c.

Ehrenberg's  
researches  
respecting  
it.

Thus, whilst one class of beings requires, as we have seen, for its existence the presence of sulphur in such a state of combination, as is found to be absolutely destructive to other kinds of life, another class secretes iron, a substance equally unsuited for the nourishment of the great majority of animals; as if it were intended, that there should be no class of inorganic productions which did not minister to the wants, and favour the production, of a corresponding order of organized creatures.

It seems worth inquiry, whether the red ochreous sediment found by Davy in the baths of Lucca may not have arisen from a similar cause, and be made up of an accumulation of infusoria; and likewise whether the colours which belong to certain specimens of rock-salt, which are sometimes of a deep-blue, but more generally red, are not owing to certain vegetable or animal matters.

Colouring  
matter of  
waters ex-  
plained.

\* *Linnean Trans.*, vol. xvii.



Ehrenberg\*, in his journey into Siberia, observed a rose-red colour in the salt lake Elton, in the steppe of Astracan, which did not appear to belong to the water, but faded on drying; and I perceive in a recent journal, that Mr. Pajcan, in his travels in Tuscany, remarked that the red substance, which is produced on the surface of water charged with marine salt in that country, is the result of an accumulation of an enormous quantity of small crustacea, of one or two lines in length, having nearly the form of a craw-fish, which live very well in brine of 15 degrees, but die when the water is further concentrated.

It is stated, that M. Darcet brought similar crustacea from certain lakes in Egypt which are charged with natron.

With respect to the blue colour sometimes observed in rock-salt, it is possible that the same kind of explanation may apply to it. I was once inclined to imagine, that it might be caused by a compound of iodine with some vegetable principle, analogous to starch, or producing with the former a similarly coloured compound; but I could detect no iodine in the specimen, and failed to reproduce the violet tinge, when the salt had been dissolved in water and crystallized a second time.

Now Ehrenberg relates, that a lake in the South of Prussia in 1819, produced a particular colouring matter very similar to indigo, which appeared to be of a vegetable nature; and Scoresby† mentions, having in 1820 observed, that the water of the Greenland sea was chequered with alternate green and blue stripes, and that these colours were produced by minute animalcules of the medusa kind.

Gases  
evolved  
from  
springs.

The gases disengaged from mineral waters have been investigated by Bischoff, Anglada, Boussingault, Longchamp, and others.

Boussingault‡ remarks, that the elastic vapours which rise so abundantly from the thermal springs of the Andes, consist of carbonic acid and sulphuretted hydrogen, and the same observation applies to most of those in connexion with volcanic formations elsewhere.

Carbonic  
acid.

Of these two gases, the one most copiously evolved is carbonic acid, which, as is well known, produces those extensive deposits of *calc-sinter*, that are so common in caverns exposed to the drippings of water, and of arragonite§, which are of rather rarer

\* On Blood-red Water.

† *Arctic Researches*.

‡ *Edinburgh New Philosophical Journal*, vol. xv. 151.

§ See a paper in the *Annales de Chimie*, June, 1834, on the presence of Arragonite in an Artesian well at Tours. I possess some also deposited from the spring of St. Nectaire in Auvergne.



occurrence in such situations. The particular circumstances determining the production of the one rather than the other form of calcareous spar, appear to be still unexplained, for stalactitical arragonite does not appear to contain any other essential ingredient than carbonate of lime, and is now supposed to arise from a difference of form in the integrant molecule of that base\*.

Another point requiring elucidation, relates to the absence of carbonate of magnesia from stalactites arising from dolomitic rocks.

Is it, that the acidulated water first dissolves the carbonate of lime, before it attacks the atomic compound of lime and magnesia, or that the attraction of carbonic acid for the former exceeds that which it exerts for the latter earth?

With respect to the extrication of carbonic acid from the earth, I have myself pointed out† the enormous quantity evolved in the vicinity of Naples, as at Torre del Annunziata, in which and in other places it frequently destroys vegetation, and likewise near the axis of the Apennine chain, midway betwixt the active volcano of Vesuvius, and the extinct one of Mount Vultur, at the Lago d'Ansanto‡.

Bischof§ has described its extrication, from the various mineral waters connected with the volcanic mountains of the Rhenish provinces, and likewise from dry fissures in the ground, where its escape is recognised by the stunted vegetation, and by finding a number of small animals suffocated round the spot.

Lecoq|| and others have mentioned the remarkable erosion produced in the rocks contiguous to the mines of Pont Gibaud in Auvergne, owing to the presence of this gas in the water which oozes through the rocks encircling them.

Brandes and Kruger, in their account of the mineral waters of Pyrmont¶, have shown, that the extrication of carbonic acid is by no means limited to the spot from whence the chalybeate

\* Mr. Crosse, amongst the experiments which he detailed at the Bristol Meeting of the British Association, stated, his having found that calcareous spar was formed on limestone, and arragonite on slate, by the drippings from the same cavern, and that he was even able by the slow action of electricity, to produce each of these minerals from the same water, charged with carbonate of lime, according as he placed it on a piece of limestone, or of slate.

† *Edinburgh New Philosophical Journal*, 1835.

‡ *Memoir on the Lake Amsanctus, and on Mount Vultur in Apulia*, printed by the Ashmolean Society of Oxford, 1836.

§ *Vulkanische Mineralquellen*, p. 251.

|| *Annales Scientifiques de l'Auvergne*, and Ferussac's *Bulletin*, vol. xvi.

¶ P. 155, et seq. See also Brandes' work on the Mineral Waters of Meinburg. Lemgo, 1832.

springs of that watering-place arise, but is observed for some distance round, wherever fissures, natural or artificial, exist.

Thus, a cavity having been made by some workmen for quarrying stone, it was found, that the air within became charged with from 36 to 48 per cent. of carbonic acid, which rose in the cavern to different heights at different times.

Its variations.

These writers report, that in winter the gas never attained so high a point as at other seasons; that in the morning, some hours after daybreak, and in the evening, soon after sunset, the mephitic air had reached its maximum, whilst at midday, when the sun shone into the cave, it was very low; that the evolution of gas was greatest before the breaking out of a storm, but diminished after it had begun; that the variations of barometric pressure seemed to exert no influence upon the phenomenon, except so far as they were connected with the occurrence of a storm; that it was greater during hot weather than cold; in calm than in windy; in a moist state of the atmosphere than in a dry one. A similar remark has been made with respect to the disengagement of carbonic acid in Auvergne\*, as that recorded as to Pyrmont, the quantity given out being so large during storms, and during the prevalence of a westerly wind, as to render some of the mines unworkable.

Kastner† also alludes to the variation as to quantity, both in the water and the carbonic acid, observed at Kissingen in Bavaria, and attributes it in both cases to a difference in atmospheric pressure, the water being forced out by the gas, and the escape of the latter checked, in proportion to the weight of the atmosphere above.

According to Mayen, the springs of Bochart have a regular ebb and flow, both as to the amount of water and of gas. The greatest difference in quantity corresponded with the interval between the first and last of the moon's quarters. At Fachingen‡ the quantity of gas evolved is said to be greatest just before sunrise, and least about two or three o'clock after mid-day.

Its amount.

The amount of carbonic acid given off has in a few instances only been determined§.

Trommsdorff found the quantity evolved from a fissure at Kaiser Franzenbad, near Egra, to amount to 5760 Vienna cubic

\* Fournet *Annales Scientifiques de l'Auvergne*, vol. ii. p. 241; or Ferussac's *Bulletin*, for 1829.

† *Archiv*, vol. xvi.

‡ Kastner, *Archiv*, vol. i.

§ See G. Bischoff in *Edinburgh New Philosophical Journal*, 1835, from Poggendorff's *Annalen*.

feet in 24 hours, whereas the water in the same time emitted was calculated at 259 cubic feet; and Bischoff notices one spring which gave out in the same time 4237 c. f., the water being 1157 c. f. and containing 1909 cubic inches of this gas, and another which evolved of gas 3063, and of water 3645 cubic feet, which contained of gas 871.

Such statements are worth recording, as enabling our successors to ascertain whether there be any secular variation in the quantity of gas evolved; and it is therefore to be regretted, that Bischoff has not mentioned the names of the springs which he had examined with reference to this point.

The uninterrupted manner in which the carbonic acid rises up through the spring is explained by Bischoff, by supposing it held in chemical solution by the water at a great depth, and therefore under an enormous pressure.

Such a supposition would enable us to understand the trifling irregularities observed in the flow of gas, without imagining that the state of the atmosphere above has any direct influence upon the energy of the volcanic operations below, since the barometric pressure, the relations to moisture, &c. of the air surrounding the spring, might favour at one time more than at another the escape of gas from the spring, or its diffusion through space. Some have supposed\*, that the water of the spring is forced upwards by the elasticity of the confined gas, but Bischoff justly remarks, that the flow of the former is too equable for any such thing to happen.

An explanation of this kind can only be resorted to in such cases as those of the Sprudel at Carlsbad, and at the Geysers in Iceland, where the spring appears, as it were, by fits and starts.

Yet in these cases the phenomenon may, perhaps, be more readily accounted for by the extrication of steam in cavities connected with the fissure through which the spring rises, as was first suggested by Sir G. Mackenzie†. Dutrochet, however, has described an intermitting spring in the Jura, which he ascribes with more reason to a periodical evolution of carbonic acid gas; though, even here an accumulation of gas taking place in a cavity connected with the spring, may have been competent to produce the phenomenon.

That Nitrogen escapes occasionally from thermal springs, is Nitrogen. by no means a new discovery, for it was remarked by Priestley

\* Berthier, *Annales de Chimie*, vol. xix.

† *Travels in Iceland*.



at Bath, and by Pearson at Buxton, before the commencement of the present century.

In thermal  
springs.

More recently it has been observed issuing from almost all the sulphureous thermal waters of the Pyrenees\*; and I have shown, that not only has it in many instances been mistaken for carbonic acid, but also that it is commonly evolved wherever thermal waters exist†.

Even when the prevailing gas emitted is carbonic acid, I find that a small quantity of residuary air is present, which consists in general of oxygen and nitrogen, but with a much smaller proportion of the former than that present in the atmosphere.

The volcanic district of Ischia affords the only example that has occurred to me, of a number of thermal springs lying together, not one of which evolves nitrogen‡.

In this case, however, we may remark, that no kind of air whatever is emitted from the waters, which therefore would seem to derive their heat, not from any volcanic processes going on at present, but from their contiguity to a mass of rock heated by antecedent eruptions.

In corroboration of this view I may state, that several springs on the skirts of Vesuvius, where volcanic operations are actually proceeding, give out nitrogen, though in much smaller quantity than they do carbonic acid; as for example, the thermal water of Torre del Annunziata, and the cold spring of Castellamare.

From the Thermals connected with extinct volcanos, azote is emitted, though for the most part in inferior quantity, than it is from springs associated with primary, or with intrusive rocks of older formation.

Its amount.

The quantity of this gas returned to the atmosphere through the medium of thermal waters is evidently considerable. I measured that emitted from the King's Bath, in the city of Bath§, nearly every day for a month during the autumn of 1833, and found that its average quantity was 267 cubic inches per minute, or 222 cubic feet in the 24 hours.

The gas consisted of 97 per cent. of nitrogen, and of 3 per cent. of oxygen, with a variable quantity of carbonic acid. Since this period, the sinking of a well in a remote quarter of the town through the lias to the depth of 250 feet, from which water rose of a temperature but little inferior to that of the

\* Anglada, *Mémoires*.

† On Hot Springs and their connexion with Volcanos, *Edinburgh New Philosophical Journal* for 1832.

‡ Daubeny, on a Spring at Torre del Annunziata near Naples.

§ See my Paper on the quantity and quality of the Gases disengaged from the Thermal Springs at Bath, *Philosophical Transactions*, 1834.



Public Bath\*, was followed, not only by a diminution in the supply of water at the latter, but also in the amount of gas emitted, which, according to the accurate observations of Mr. George Spry, of Bath, made in the beginning of August in this year†, appears not to average at present more than 170 cubic inches per minute, whilst the quantity of water discharged at the original spring, was reduced from 120 gallons to 75, in the same interval of time.

Thus the relation between the decrease of gas and of water kept pace very nearly one with another ; for,

$$\text{as } 150 : 222 :: 75 : 111.$$

The slight excess of gas may have arisen from the more scrupulous manner, in which Mr. Spry prevented its escape from all the apertures in the bath, excepting those from which he collected it, than had been previously done by myself.

I have since estimated the amount of gas emitted from the thermal spring of Buxton at about 50 cubic inches per minute, and find that M. Longchamp determined the quantity at one of the springs, Cauterets in the Pyrenees, as being about 7.1 cubic inches, whilst he calculates that of the water given out by the same during an equal space of time at 1584, or nearly 226 times the amount.

The above are nearly all the observations we at present possess, with respect to the quantity of nitrogen emitted from thermal springs, though it would be desirable to obtain in every instance an exact register of this, as well as of the quantity and temperature of the water itself, as affording us the data for determining at some future time, whether any secular variation is taking place in the quality of each spring in these several respects.

In the table, therefore, at the close of the present Report, I have registered in two separate columns all the observations I could collect, on the quantity of gas and water emitted within the space of twenty-four hours by the springs named.

It is worth remarking, that an evolution of nitrogen gas is not altogether peculiar to thermal waters. In cold springs.

I detected it issuing pretty abundantly from a spring near Clonmel, which possessed the common temperature of those in the neighbourhood ; another emitting the same has been de-

\* M. Arago, in his *Annuaire* for 1836, mentions, that the same falling off of the hot spring of Aix, in Provence, took place in consequence of the sinking of a contiguous well, but it is remarkable that in this case the water of the latter was cold.

† Viz. in 1836.

scribed, as occurring near Inverkeithing in Scotland, by the Rev. W. Robertson\*, and I have been informed of a third in Shropshire by Mr. Murchison.

Oxygen.

In one or two cases oxygen is said to predominate in the air evolved, as Robiquet says is the case at Vichy; but as he adds, that it is only found, after the water has been standing in the reservoir long enough to be covered by a vegetable slime, I conceive this gas to have arisen from the decomposition of carbonic acid within the tissue of the plant, under the influence of solar light.

Carburetted hydrogen.

Carburetted hydrogen has in many instances been observed to issue from springs, as well as from clefts in the earth, as at the Pietra Mala on the Apennines, and at St. Barthelemi near Grenoble, where the gas, when once kindled either by accident or design, maintains a continued flame, until pains are taken to extinguish it.

It has also been observed in many parts of the world to issue copiously from salt springs, as at Medonia in the State of New York, in China, &c.; and a curious proof that the salt, with which these springs are impregnated, had been deposited under pressure, is afforded by the fact, that at Wielichza in Gallicia its cavities contain carburetted hydrogen in a condensed state, so that on immersing a lump of this salt in water, a series of small detonations is heard during its solution, in consequence of the sudden expansion of the gas on escaping from its prison.

It is an interesting circumstance, to find this phenomenon continuing in the very spots, in which it was observed during the periods of Grecian history.

I have quoted in another place†, an instance of its occurrence among the Chimariot mountains of Albania, where ancient writers speak of a nymphenm as existing, by which they meant to express, that a stream of inflammable gas had there been observed.

Sulphuretted hydrogen.

The same permanency seems also in some cases to be the attribute of sulphureous waters; for the hot springs of Bithynia, which modern travellers describe as impregnated with sulphuretted hydrogen, appear from the accounts of Greek writers‡ to have been similarly constituted nearly two thousand years ago.

These, however, which are *thermal* sulphureous springs, pro-

\* *Edinburgh New Philosophical Journal*, 1829.

† Memoir on the Bath Waters above quoted.

‡ See the Poem “Περὶ τὰ ἐν Ἰνδοῖς Θέρμα,” extracted from the Greek Anthology in my *Description of Volcanos*, 8vo, 1826.

bably derive their origin from a totally different cause, to that which impregnates cold ones with this same principle.

The latter in some instances undergo, within a very short period, a material alteration in point of strength.

Thus a sulphureous spring at Willoughby, in Warwickshire\*, yielded me in the autumn of 1828, 16·9 cubic inches of sulphuretted hydrogen to the gallon.

In the April following, I could detect only 12·65 cubic inches, and in the autumn of 1834 only 5·2.

Whilst on this subject, I may mention, that Professor Anglada of Montpellier†, has satisfied himself by a detailed examination of the sulphureous springs of the Pyrennees, that no one of them contains sulphuretted hydrogen in a free state, but that in every instance this principle is united to an alkaline base, with which it constitutes an hydrosulphuret.

Finding this to be the case so generally, he has proposed a classification of sulphureous springs founded on this principle, arranging them, according as they contain the above gas in a free state, or combined with one, or two atoms of a base.

By applying the same reagent (the arsenious acid,) which M. Anglada had employed, I was led to conclude, that the springs of Aix la Chapelle and Borset were similarly constituted, and indeed such would necessarily be the case, wherever the soda in the water was not impregnated with carbonic acid, nor could there well exist in it any free sulphuretted hydrogen, until the whole of the alkali was thus saturated.

Hence in affirming that the gas of the Pyrenean springs always occurs in this state of combination, M. Anglada has (apparently unconsciously) confirmed the statement, which he questions, as to the existence of caustic soda in the water.

We have already considered whether under ordinary circumstances mineral springs are subject to vicissitudes, either as to temperature, as to the quantity and quality of their fixed and gaseous constituents, or as to the amount of water discharged.

Influence of  
earth-  
quakes  
upon  
springs.

It will be proper, however, before proceeding further, to notice what has been observed, with respect to the influence exerted upon them in any of the above respects by earthquakes, which are stated in some cases to have affected particular springs in an extraordinary manner.

During an earthquake in 1768 at Vienna, the spring of Baden became more copious than before, and the evolution of sulphuretted hydrogen more abundant‡.

\* *Philosophical Magazine*, Jan. 1835.

‡ Kastner's *Archiv*, vol. v.

† *Mémoires pour servir*, &c.



An earthquake in 1692 is said to have affected the spring of Spa in a similar manner; and one that happened in the surrounding district communicated to the spring of Bagneres de Luehon an increase of temperature.

But these are effects produced by earthquakes in the vicinity of the springs; more remarkable is the influence exerted upon them by similar subterranean movements taking place in distant quarters.

Thus during the great earthquake of Lisbon, the hot spring of Toeplitz in Bohemia, betwixt the hours of eleven and twelve in the day, is recorded to have become turbid, and then to have gushed out so copiously as to overflow the well. The water assumed a red tinge, and was suspected to have become hotter. At the same time the hot spring of Pesth in Hungary is said to have shown a similar increase of temperature.

This sympathy with the subterranean movements of a distant quarter will appear less extraordinary, when we recollect, that the same earthquake is said to have been felt by the workmen in the mines of Derbyshire.

In other cases, the connexion of the spring with the subterranean movement has been evinced, perhaps as decisively, by the opposite effect occurring.

Thus in 1660, in consequence of an earthquake, the thermal waters of Bagneres de Bigorre were for a short time suspended; during one that occurred at Naples, the Sprudel at Carlsbad is stated to have remained tranquil for six hours; and in the great earthquake of Lisbon, that of Aix in Savoy ceased to flow.

Lastly, in a few instances, the existence of a thermal spring has seemed to act as a safety valve, and to secure the immediate locality from those natural convulsions which affected the neighbourhood. Thus an earthquake which shook the whole district around was not felt at Carlsbad itself, and the same remark has been made at Wiesbaden.

I have now stated the more recent additions that have been made to our knowledge as to the contents of mineral springs; but the undertaking would be incomplete, if I passed over without comment those, which, though not known to contain any peculiar chemical ingredient, seem nevertheless to produce certain decided effects upon the animal œconomy.

Springs exerting a peculiar action upon the animal œconomy.

For to refuse credence to the reports given by medical men with respect to the salutary or injurious effects of a particular water, merely because the chemist can discover in it no active principle, would seem a proceeding not less unphilosophical, than that of which our predecessors were guilty, in treating as fabulous the accounts given of stones that had fallen from the



sky, because they did not understand how such ponderous masses could have continued suspended in it. And on the other hand, granting that a spring possesses peculiar virtues, we must suppose that it differs, either in its mechanical, or chemical properties, from the rest.

Accordingly those springs, which are believed on good authority to possess medicinal virtues, ought properly to find a place, not merely in a professional treatise on the subject, but also in one that affects to consider it scientifically.

Most countries afford examples of springs, that appear almost chemically pure, to which medicinal qualities have been accorded: thus Gastein in the Saltzburg, and Loueche in the Swiss Alps, amongst thermal waters; and Malvern in England, amongst cold ones\*, are very sparingly charged with mineral matter, and what they contain consists of ingredients apparently not calculated to exert any action upon the animal system.

How far the reputation enjoyed by these springs may be owing to other causes, such as the purity of the air, the change of diet, mode of living, &c., it is for the enlightened physician to inform us, and an interesting field of physiological inquiry seems to be open to him, in examining the effects exerted upon the system by that long-continued immersion in warm water, to which it is the practice of invalids in several of these watering places to resort†.

It is remarkable, that a very large proportion of those celebrated warm springs lie at a considerable elevation. Thus Gastein is 3100 feet above the sea, Loueche 4400, and Pfeffers 2128 feet: now one may easily imagine, that the exhalation from the surface of the body, and the activity of the functions thereon dependent, may be much promoted by the practice of the invalid, of remaining alternately immersed, in water of so high a temperature, and in so rarified an atmosphere. If, however, after taking this and other circumstances into account, the testimony, in favour of some specific action derived from the spring itself upon the animal œconomy, should seem unexcep-

Causes of  
their agency  
considered.

\* Dr. Hastings, in his *Illustrations of the Natural History of Worcestershire*, 1834, states, that its efficacy is found to be very considerable in arthritic, calculous, dyspeptic, and scrofulous cases.

† Dr. Gairdner doubts the statement I had on a former occasion made on this point; but I can assure him, from personal observation at Loueche, and by quite sufficient testimony as to Gastein, that in both these baths it is the practice to remain immersed, for periods of time, varying from four to ten hours, during the process of cure. At Buda too, and at Glasshutte in Hungary, the peasants continue in the public baths for a length of time, that would quite astonish an English physician.

In the presence of iodine and bromine.

tionable, the chemist ought to consent to regard this action as indicative, of undiscovered principles, or modes of combination.

Thus certain salt springs in Piedmont had acquired from time immemorial a reputation in the cure of goitre, which the nature of their then known mineral impregnation would not explain.

Recent investigations have, however, shown, that these springs contain a small quantity of iodine, the very principle now found most efficacious in this and other glandular disorders.

The superior efficacy attributed to the waters of Cheltenham and Leamington over mere artificial solutions of sulphate of soda, &c. of the same strength, was difficult of explanation, until chemical analysis had shown that, in addition to the more common ingredients, these springs contain portions of two active principles, iodine and bromine, wanting in the imitation of them.

In like manner chemists, in the pride of half knowledge, may often have smiled at the faith reposed in the water, of Ashby-de-la-Zouch in Leicestershire, and of Krentynach, in the Palatinate, both which, until lately, appeared to be little more than mere saturated solutions of common salt.

But the advance of science has shown, that these two springs are precisely the ones most fully impregnated of any perhaps known with salts of bromine, and therefore most highly charged with the properties of that active principle.

In the absence of air.

It has long been a vulgar notion, that goitre arose from drinking snow water, and this opinion, which was derided by men of science, seems to be in some measure substantiated by the recent researches of Boussingault in the Andes\*.

That naturalist commences by showing, that the goitre of the above elevated region can arise, neither from the humidity of the climate, as had been supposed by some, nor from the nature of the earthy ingredients of the springs, as had been imagined by others.

He then observes, that persons who habitually employ as their beverage water devoid of its due proportion of air (whether that deficiency be owing, to the rarefaction of the atmosphere on the high table land on which it lies, or to the circumstance of its being immediately obtained from the melted snow of the mountains) are subject to this disease, whilst persons who take care to aerate their water before drinking it, as may be done by those residing at a moderate elevation, by merely exposing it to the atmosphere for 30 or 40 hours previous, escape the deformity.

For the same reason, a river, which at a high level appears to

\* *Annales de Chimie*, 1833.

cause goitre, has no such tendency at a lower one, so soon, that is, as its waters have become duly aerated in the progress of their descent.

In like manner, water which rises from calcareous rocks, or which has become stagnant in lakes, has a tendency to produce goitre, not by reason of its solid contents, but owing to the absence of the usual quantity of air.

Boussingault also relates the extraordinary fact, that those provinces, which are provided with salt containing iodine, are not affected with goitre, whilst in others, where the salt is destitute of that principle, the disease is endemic.

There has likewise been an attempt lately made by a German physician\* to mark a difference in the electrical condition of one of those springs, which, though almost chemically pure, seemed nevertheless to possess active properties.

In their electrical condition.

He states, that the water of Gastein conducts electricity better than common water would do. Such a statement, however, cannot receive any credence, until all the details of the method, by which a result so paradoxical was arrived at, have been submitted to the judgement of scientific men.

Kastner had previously endeavoured to establish the same in the case of the waters of Wiesbaden, but the fallacy of his experiments is now generally admitted.

Equally fanciful appear the opinions of those, who attribute to natural thermal springs a greater capacity for heat than belongs to artificially prepared waters of equal temperature, and who maintain that they cool more slowly in consequence.

In their capacity for heat.

M. Longchamp, in France, by experiments on the waters of Bourbon; Professor Gmelin, of Heidelberg, by similar ones on those of Baden-baden; Reuss, Neumann, and Steinmann by some on the springs of Carlsbad; and Schweigger and Fieinus by others on those of Toeplitz, have exposed the fallacy of this notion; and have shown, that in reality no difference exists in this respect between the one and the other†.

Let us next proceed to consider the improvements, that have been lately introduced into our methods of analysing the solid and gaseous constituents of mineral waters.

Analysis of mineral waters.

Most chemists are by this time familiar with the simplification upon the plan of proceeding, which we owe to Dr. Murray‡ of Edinburgh, in consequence of his having pointed out, that as the salts existing in a spring need not be the same with those we obtain on evaporation, and as salts viewed as incompatible may

General principles.

\* Dr. Pettenhofer.

† Consult Bischoff, *Vulk. Mineralg.*, p. 364.

‡ *Transactions of the Royal Society of Edinburgh*.



coexist in a state of weak solution, the analysis of a mineral water consists in nothing more than in determining the nature and amount of the several acids and bases which it contains. But Berzelius has further contended\*, that everything beyond this, which the chemical analysis professes to give, is a matter of hypothesis, and that in concluding the salts, actually present in the water, to be necessarily the most soluble compounds, that could be formed out of the acids and bases present, Murray went further than he was justified, either by experiment or analogy, in doing.

The Swedish chemist, on the contrary, contends, and apparently with much justice, that, consistently with the views of Berthollet on the influence of the mass, we ought to suppose as many salts to exist in a mineral water, as can be formed out of the constituents present, whilst the proportion, in which these salts exist, is a point which we cannot obtain data for calculating, until we are able to estimate numerically, the relative force of affinity subsisting between the ingredients.

According, therefore, to the received views on this subject, the chemist ought in strictness barely to set down, as the results of his analysis, the respective weights of the acids and bases present.

If he does more than this, and professes to combine these principles into salts, it should be understood, that he acts merely in conformity with existing usage, and in order to convey to the public the impression, that those waters, in which he has found such and such acids and bases, act upon the system in a manner similar to that, which the salts he states to exist in them are considered calculated to do.

Particular  
improvements.

With respect to the particular improvements introduced into this department of chemical analysis, I may particularize the following :

To distinguish barytes or strontites from lime ;

A solution of sulphate of lime has been proposed as a test for barytes, or strontites, in a mineral water.

If either of these bases exists therein, a precipitate is formed, whereas, if lime alone is present, no effect takes place on the addition of this reagent.

barytes  
from strontites.

An easy method of separating barytes from strontites has been invented by Liebig†, who treats the mixed solution with iodate of soda, this forming, an insoluble precipitate with the baryte, but a soluble compound with the strontian.

Another method‡ has lately been proposed for the same object, namely, that of adding neutral chromate of potash to the

\* In his Analysis of the Carlsbad water, *Annales de Chimie*, vol. xxviii.

† Already noticed in Mr. Johnson's Report.

‡ *Philosophical Magazine*, March 1836.



mixture of strontian and baryt, whereby a soluble salt is formed with the former, and an insoluble one with the latter.

The precipitated chromate of barytes must be heated to redness before it is weighed.

The common method of detecting lithia in mineral waters is to precipitate it by phosphoric acid, a little phosphate of soda being first added to the solution, in order to make sure of the whole of the phosphate of lithia being thrown down. Lithia.

Kastner\* proposes as an improvement, that the solution should be neutralized by sulphuric acid, and then reduced to dryness.

Alcohol will take up the sulphate of lithia without affecting the other sulphates, and the solution on being evaporated, and then redissolved in as small a quantity of water as possible, may have its lithia thrown down, in combination with phosphoric acid, by phosphate of soda.

An elegant method of detecting nitric acid was proposed by Dr. Wollaston. It consisted in adding to the liquid a few drops of muriatic acid, and a little gold leaf, which latter will be dissolved if nitric acid be present †. Nitric Acid.

Döbereiner‡ has lately suggested another method, which enables us to determine also the amount of nitric acid, even when in small quantities.

He mixes the suspected liquid with an equal quantity of concentrated sulphuric acid, and introduces the mixture into a graduated tube, placed over quicksilver. A slip of copper is then added, and the mixture warmed. Sulphate of copper is thus formed, and an amount of azote collected equivalent to that of the nitric acid present.

A more convenient plan of conducting the experiment would seem to be, that of heating the suspected liquid in a glass tube, containing a little metallic copper and sulphuric acid, and receiving the gas over mercury.

I have already noticed the probability that ammonia has often been overlooked in our analyses of mineral springs. To detect it, sulphuric acid should first be added to the water, which may then be concentrated, and evaporated in a water-bath, after which the addition of quicklime will separate the ammonia, and render it sensible both by its odour and alkaline reaction. Ammonia.

The received method of estimating the amount of bromine, Bromine.

\* *Archiv*, vol. xvi.

† Becquerel has proposed an electro-chemical method of effecting the same object founded on the same principle. *Traité de l'Electricité*, vol. iii. p. 325.

‡ Berzelius, *Jahresbericht*, 1832, p. 162.

when present in a water, together with chlorine, is stated in my work on the Atomic Theory\*.

It is nothing more than an application of the method suggested by M. Gay-Lussac for calculating the proportions of soda and potass, to the case of bromine and chlorine, and labours in common with it under the objection, that the inference is deduced, not from a single experiment, but from a comparison of at least two; and that a very trifling inaccuracy in either, being multiplied in the calculation founded on them, vitiates the whole result.

It would be well, therefore, if a direct method of determining the same could be hit upon; and for this reason I set down one suggested by Lowig, which has already found a place in Professor Johnston's Report on Chemistry, published in the first volume of our Reports.

The dried mixture of chloride and bromide is to be heated in a stream of chlorine, so long as any bromine appears to be disengaged. The chlorine and bromine which pass over are received into a solution of caustic potass, by which chloride of potassium and chlorate of potass, together with bromate of potass, are produced.

Having neutralized the potass with nitric acid, nitrate of silver is added to precipitate the chlorine and the bromic acid.

The precipitate, after being washed, is introduced moist into a bottle, and barytic water added. A soluble bromate of barytes is thus formed, whilst the chloride remains untouched. The solution being poured off, the excess of barytes is separated by carbonic acid, and the bromate of barytes is thus left in a state of purity.

Dr. Osann† has lately suggested another mode of separating these two principles.

It depends on the greater volatility of chlorine than bromine, and on the circumstance, that chloride of silver becomes of a violet colour after exposure to light, whilst bromide of silver is rendered greyish black.

He therefore expels the chlorine and bromine by means of sulphuric acid, slowly distils over the two, and makes them pass into a solution of nitrate of silver. The precipitate is from time to time tested by exposure to light, and when found to assume the appearance belonging to bromide of silver, that which comes over is set apart, and reckoned as such.

In order to obviate the objection, arising from the circumstance, that there is an intermediate period when the chlorine

\* *Introduction to the Atomic Theory*, p. 89. The same method was followed by Dr. Ure in his analysis of the Ashby water; *Phil. Transactions*, 1834.

† Poggendorff's *Annalen*, 1831.

and bromine come over together, Osann proposes to stop the distillation, exactly at the point at which the precipitate is an equal mixture of the two acids. The deficiency of bromine in the solution is thus compensated for by the chlorine obtained. It is evident, however, that a very practised eye would be required, in order to obtain correct quantitative results by such a method as the above.

The same author proposes to separate iodine from chlorine, by causing the mixture to pass over in a state of vapour into a solution of potass, and then precipitating it with arsenious acid or arseniate of ammonia.

The iodine unites with the arsenic, which latter is precipitated by sulphuretted hydrogen. This being got rid of by oxide of lead, the iodine is obtained by uniting it with silver.

Henry Rose\* has proposed a new method of distinguishing between the protoxide and peroxide of iron. Oxides of iron.

When muriatic acid is added to a mixture containing both these oxides, the protoxide is converted into a protochloride, the peroxide into a perchloride.

Now metallic silver robs the latter of its half-atom of chlorine, converting it into the protochloride, and hence the increase of weight in the silver added, enables us to calculate the amount of peroxide of iron originally present.

Another method for the same object has been proposed by Fuchs†. It consists in digesting the solution of protoxide and peroxide in an acid, with carbonate of lime or of magnesia, by either of which the peroxide is precipitated, whilst the protoxide remains untouched.

This peroxide is obtained in a state of mixture with the earth and acid employed, and must be separated from both by the ordinary means.

The only difficulty consists, in preventing the weight of the precipitate from being increased during filtration, in consequence of the conversion of some of the protoxide into peroxide.

In order to prevent this as much as possible, the precipitate should be washed repeatedly with warm water, before the supernatant liquor is thrown upon the filter.

For the detection of organic matter in mineral waters, Dr. Davy has suggested the employment of a solution of nitrate of silver‡. The blackening, which usually takes place in this fluid upon exposure to light, is attributable to the presence of organic matter; for if care be taken to purify the water, light produces no change. Organic matter.

\* Berzelius, *Jahresbericht*, 1832, p. 164.

† *Jahresbericht*, 1832, p. 164.

‡ *Edinburgh New Phil. Journal*, 1828, p. 129.



When, however, this test is employed, we must first assure ourselves that no chlorides exist in the solution ; for chloride of silver, which would be formed, is blackened by the sun's rays, even though no organic matter be present.

Gases.

For determining the quality and amount of the gases chemically combined with a mineral water, Mr. Walcher\* suggested a modification in the common apparatus, with a view of obviating the error likely to arise from a portion of the water being driven over by the ebullition.

In his experiments, the glass globe containing the water to be boiled was connected, air-tight, to a little phial, from which proceeded a sigmoid tube, passing under mercury, or into the vessel containing the substance intended to absorb the gas.

Let us suppose, for instance, that our object is to ascertain the amount of nitrogen and oxygen which a water contains. In that case we fill the phial with carbonic acid, and the graduated tube with solution of potass. The air expelled by ebullition, together with a portion of the water itself, entering the phial, expels the air, which passing into the tube, is robbed of its carbonic acid by the potass.

After the experiment is over, the air remaining in the phial may easily be transferred into the jar, and the water which came over may be passed back again into the glass globe, in order that it may be treated like the rest.

In this manner, perhaps, a somewhat greater degree of accuracy may be attained, than where a glass globe with a sigmoid tube alone is employed.

But I conceive that the utility of Mr. Walcker's plan will be chiefly felt where the object is to ascertain the amount of sulphuretted hydrogen, or of carbonic acid in a mineral water, by boiling it, and passing the gases over into a solution calculated to absorb them.

In such cases, if any portion of the water comes over with the gas, the result is entirely vitiated ; and to prevent this, there seems to be a convenience in the intervening bottle, which, however, where sulphuretted hydrogen is expected, should be filled with some gas not containing oxygen.

Sulphuretted hydrogen.

After all, however, the simplest mode of ascertaining the amount of sulphuretted hydrogen is by adding directly to the water some reagent, which precipitates it in a state of combination.

Mr. Richard Phillips, in his analysis of a spring near Weymouth†, has employed the nitrate of silver, which appears to be

\* Brande's *Journal of Science* for 1828.

† *Phil. Mag.*, vol. iii. p. 158.

preferable to any other substance, as the only combinations formed are the chloride and the sulphuret, of which the former is soluble in liquid ammonia, whilst the latter is not acted upon by it.

I have already stated, that M. Anglada considers the sulphuretted hydrogen of the Pyrenean springs to be combined with an alkali. In order to determine whether this be the case or not, the test he employs is a solution of arsenious acid\*, which gives a yellow precipitate with the free acid, but does not affect solutions of the hydrosulphurets†.

Azote is usually detected by negative trials, but an ingenious method of directly proving its presence has lately been suggested.

Azote.

This is, to melt a piece of potass in contact with a slip of zinc in the air suspected to contain it, suspending over the two a piece of turmeric paper, moistened.

The water of the potass will thus be decomposed, its oxygen passing over to the zinc, and the hydrogen being liberated. The latter, at the moment of its separation, unites with any azote that may be present, forming ammonia, which produces its characteristic effect upon the test paper.

The fabrication of factitious mineral waters, being entirely dependent on the knowledge we may possess of their chemical constitution, seems to claim a place immediately after the consideration of their analysis.

On factitious mineral waters.

The subject is one which has excited considerable interest on the Continent, in consequence of the labours of Dr. Struve of Dresden, who has devoted himself, for a number of years past, to the imitation of those natural springs which possess the highest reputation amongst his countrymen.

To do this completely, considerable skill in manipulation, and a minute attention to several apparently unimportant circumstances, are found to be requisite.

As the first step of the process, the water intended to be mineralized, must be impregnated with the same amount of carbonic acid, and the other gases which its natural prototype possesses; and, in order to effect this object, the whole of the atmospheric air existing in the water must be previously expelled, and the carbonic acid added, under a pressure, neither greater nor less, than that to which it is subjected in nature.

All this time the fluid must be kept at the exact temperature

\* *Mémoires pour servir*, &c., vol. ii.

† Prof. Johnston mentions in his *Report on Chemistry* another method, p. 460.

which the natural spring maintains, and access of air during the continuance of the process must be scrupulously prevented. This done, the same fixed ingredients must be presented to the water, and no one principle omitted, however small may be its quantity in nature, or however inert it may in itself be, it being recollected that the introduction of a fresh substance, by the affinities it exerts, alters, according to the Berzelian doctrine, the proportions of all the salts previously existing in the water. Nor is this all, for it is necessary that the water should be maintained at the same temperature and under the same pressure till the very moment of drinking it.

Similar precautions must be adopted during the act of bottling, the bottle being previously filled with carbonic acid before the water is passed into it: for if the vessel were already occupied by atmospheric air, much of the carbonic acid existing in the water would be expelled, and, consequently, a portion of the earthy or metallic ingredients be thrown down.

To fabricate, therefore, a successful imitation of a natural spring, a more complicated apparatus is employed than was formerly believed requisite, and the water must be made to pass through various successive operations, before the process is wound up by the addition of the saline ingredients by which it is mineralized.

When thus prepared, the factitious water will coincide with the natural one in taste, smell, specific gravity, and other physical properties. The gas-bubbles will rise in the same form, and spontaneous decomposition will take place within the same period and to the same extent.

The mineral waters prepared by Struve really seem to fulfill these conditions in a great degree, and have stood likewise the test of a rigorous chemical analysis, without the detection of any deviation from the original.

Their pretensions, indeed, have been occasionally sneered at, as might be expected, by the physicians and chemists, who have taken under their patronage the interests of any one of those natural waters, for which the artificial ones are offered as substitutes.

“Dr. Struve,” says one\*, “professed to prepare genuine Carlsbad waters, prior to the analysis of Berzelius, who detected in it six or eight new ingredients. He went on doing the same after the discoveries of this great chemist had been announced. Perhaps ten years hence we shall find half a dozen more principles in the water. But no matter, for we shall always find at Dr. Struve’s a supply of the true and genuine Carlsbad water.”

\* Pécqz, *Traité des Eaux de Wiesbaden*, p. 93.



This is scarcely candid criticism. It may be admitted, indeed, that an artificial mineral water can at best be only a near approximation to the natural one, and that we can never be absolutely sure of having arrived at a knowledge of all the contents of the latter.

Yet even if we take the very case of the Carlsbad waters, which are quoted against Struve, how minute is the difference between the analysis of Berzelius, and that of Klaproth, which he had previously taken as his guide.

Struve\* indeed calculates, that during a month's use of these waters, an individual who drank ten glasses full of them each day, would not have consumed quite five grains of those ingredients, which Berzelius's analysis shows to have been overlooked, namely,

Of fluete of lime . . . . .	2.58 grains
Carbonate of strontia . . . . .	0.77 „
Phosphate of lime . . . . .	0.18 „
Carbonate of magnesia . . . . .	0.67 „
Subphosphate of alumina . . . . .	0.26 „
<hr/>	
Total . . . . .	4.46 „

When, therefore, we have a mineral water prepared by art, which possesses the same apparent physical properties belonging to the one which it is intended to imitate, and when the best analysis, which the existing state of chemical science admits, confirms this identity, there is surely no such antecedent improbability, in the idea of its possessing similar medicinal virtues, as should indispose us to receive the reports of medical men, when they assure us that in this latter respect also the same correspondence subsists†.

Still, however, as the natural spring will always deserve a preference, I cannot think that Dr. Struve is happy in fixing, as the main seat of his operations, upon Dresden, a city lying not very remote from any of the springs which it has been his business to imitate.

It is rather in the branch establishments which have been set up under his auspices, at Moscow, Warsaw, Königsberg, and Brighton, that the value of his method will be appreciated, since the carbonated waters which he prepares are scarcely to be met with in these countries, lying as they do beyond the range of those volcanic phenomena, which extend from the

\* *Ueber künstlich. Mineralwasser.*

† Half the substance of Struve's work consists of the statements of different physicians as to the efficacy of his artificial waters.

mountains of the Taunus to those of Bohemia and Silesia, and of which this class of springs are among the consequences.

Products of  
springs.

Before I conclude this portion of my subject, it may be proper briefly to notice, to what extent mineral waters appear to have affected the geological structure of certain parts of the earth.

Trivial as this influence may seem at present to be, yet it will be sufficient to refer to Mr. Lyell's well-known work, as establishing the position, that no inconsiderable portion of the crust of the globe, in volcanic countries at least, is attributable to the deposits which they have occasioned.

Calcareous.

Without pretending to describe the vast accumulations of travertin formed by carbonated springs, in Tuscany, in the Campagna di Roma, in Hungary, &c., I shall merely remark, that the resemblance, which some varieties of this deposit bear to the materials of older calcareous rocks is so great, and the passage from one to the other so imperceptible, that we are naturally led to suspect the latter to have been often produced in the very same manner.

Thus some varieties of travertin are undistinguishable in hand specimens from marble, as that formed by the waters of Civita Vecchia in the Campagna\*. Others, like that near the town of Nonette, on the right bank of the Allier in Auvergne, might be mistaken for the Juratic limestone†; and the shelly limestone, now forming at the bottom of many lakes, bears the most complete resemblance to certain tertiary deposits‡.

Even the concretionary structure of the limestone of Sunderland, a rock, which, though existing in the magnesian limestone formation, and in the midst of a powdery variety of dolomite, is itself almost wholly calcareous, is imitated by the spheroidal masses of travertin that occur at Tivoli and at Carlsbad, and may have resulted from the same gyratory motion of its component parts during their deposition, to which Mr. Lyell has ingeniously attributed the concentric circles of the latter deposit. The absence of magnesia confirms this suspicion.

In the ocean it is probable that mineral springs fulfill a still more important office—that, namely, of supplying with calcareous matter those Molluscæ which are building up extensive coral reefs; for, as I observed many years back§, the muriate of lime which the ocean contains, would long ago have been exhausted by the operations of these animalcules, supposing them to have the power of decomposing it, and of appropriating its

\* Lyell's *Geology*, vol. i. p. 198.

† Lecoq and Bouillet, *Vues et Coupes d'Auvergne*, p. 131.

‡ Lyell, *Geol. Trans.*, 2nd Series, vol. ii. p. 73.

§ *Inaugural Lecture on Chemistry*, Oxford, 1821.

base, unless we assume this salt to have existed originally in sea-water, in such a proportion as would have been seemingly incompatible with marine life.

Mr. Lyell has also justly remarked, that the same volcanic agency, which has raised the bed of the ocean, sufficiently to admit of its serving as a base for the coral reefs which form within it, also, by the carbonic acid which it causes to be emitted, occasions a larger quantity of that calcareous matter, which they require, to be dissolved by the water in their vicinity. Gypseous deposits are likewise often produced by springs of the present day, as noticed, with respect to those of Baden near Vienna by Prevost, and that near the lake Amsanctus by myself.

How far the beds of sulphur which occur in volcanic districts, and the sulphate of lime which is associated with most beds of salt, can be referred to the same, will be discussed afterwards; but we must take care not to confound (as some writers appear to have done,) the creative effects of mineral waters, with their decomposing agency. The latter is illustrated in the deposits of the mud-volcanos, as they are called, of South America, where vast masses of matter, chiefly argillaceous, derived from felspathic rocks decomposed by water and acid vapours, are washed down into the low country, and there constitute extensive beds.

Argilla-  
ceous.

The rocks described by Menge\*, as formed by hot springs in Iceland, are probably of the same description, for it is impossible to follow this author in that portion of his statement, in which he represents basalt, lava, and trap porphyry, as in the act of being produced in them. He appeals indeed to the fact of his extracting from the midst of a boiling marsh, a mass of matter, which when broken, exhibited the characters of basaltic lava in the centre, and towards the surface passed gradually into red and grey mud; but it seems just as easy to explain this, by the decomposing influence of the water extending gradually from the circumference to the centre, as by the contrary process taking place in the reverse direction.

The siliceous formations actually deposited at the present time by springs, appear to be comparatively insignificant, the most important being those of Iceland, and of St. Michael in the Azores. It is probable, however, that under the sea, where the influence of heat, and the chemical affinity of alkali, are heightened by the effect of an enormous pressure, beds of considerable extent may be produced in this manner.

Siliceous.

Iron pyrites has been observed in a deposit from the thermal springs of Chaudes Aigues in the Cantal, owing probably to the

Ferrugi-  
nous.

\* *Edinb. Phil. Journal*, vol. ii.



decomposition of sulphate of iron by organic matter\*, and ochre has been often observed forming, in the midst of travertin, small beds or veins, which owe their origin to the deposits from ferruginous waters†.

Bituminous.

To petroleum springs, which so commonly arise from the operations of volcanic fire, Mr. Lyell is disposed to attribute the bituminous shales present in geological formations of different ages.

Thus the phenomena of mineral waters afford a clue to the origin of various constituents of our globe, which it would otherwise have been difficult to explain by the mere agency of water, and relieve us from the necessity of assuming the operation of causes that have ceased to exist, in order to explain the occurrence of minerals or beds composed of silica in the midst of Neptunian formations.

Origin of springs in general.

Having now collected the principal facts of recent observation which have fallen under my notice with respect to the natural history of mineral waters, I will next proceed to state what is known with respect to their origin, and the causes of their respective peculiarities.

The notions entertained by our forefathers with respect to the formation of land springs by the infiltration of sea-water, deprived of its saltiness by its passage through the intervening rocks, have long given place to the more rational theory which attributes them to the large reservoirs of rain-water, collected within the porous strata, and forced out by hydrostatic pressure, wherever a natural or artificial opening was created for them.

A German writer, however, named Keferstein‡, has attempted to cast doubts upon this explanation, and to substitute for it one founded upon certain fanciful speculations with respect to the earth's vitality, which seem to be the fitting progeny of an earlier stage of physical research.

The earth being, according to him, one great animated being, performing functions of a nature analogous to those discharged by the living creatures that exist upon its surface, the production of springs is regarded as the result of its respiration; and the discharge of steam, carbonic acid, and nitrogen, together with the absorption of oxygen, is viewed as originating in processes similar in kind, to those which are carried on by the lungs of animals.

It is not my purpose to combat this strange hypothesis, though if there be any in this country who have already become converts to it, they may perhaps find excuses for applying its

\* Berthier, *Annales des Mines*, 1810.

† Lecoq, *Vues*, &c. p. 120.

‡ In Kastner's *Archiv*, vol. iii. p. 359, and in his work entitled, *Deutschland geologisch dargestellt*. Halle.

principles to the case of springs, by espying difficulties in certain special instances to the application of the received theory.

It may, however, be sufficient for my purpose to remark, that, be the difficulties in question real or apparent, they are not, at least, of moment enough, or applicable to a sufficient number of cases, to induce more sober theorists to adopt the views, which it has been proposed to substitute for the received ones.

The majority of naturalists will be contented with appealing to the researches of Dr. Dalton, who, in a paper published in the *Manchester Memoirs*\*, has shown the adequacy of the water which descends from the heavens in the part of England he inhabits, to supply the springs of that district, notwithstanding the loss arising from evaporation.

There appears indeed, from his calculation, to be an excess of 2 inches per annum in the latter beyond the amount of rain and dew which fall; but this excess Dr. Dalton thinks may be explained without resorting to any other supposition than the one alluded to.

Yet, although the general theory will scarcely admit of dispute, it is satisfactory to collect facts on this subject, in order to compare with the former; and one singularity has been observed in the instance of springs issuing from chalk, which appear to be most copious in June, and least so in December†.

This, however, seems referable to the slowness with which water percolates so thick a stratum as the chalk, and is analogous to what has been observed with respect to terrestrial heat, where the excess of summer temperature does not reach the utmost limit of its progress into the earth till about the middle of winter.

Mr. Henwood‡ has also stated the quantity of water given out by the springs in a certain district of Cornwall, as determined by the amount raised by the engines in particular mines; and concludes, that it is greater by one third than that of the rain falling in the country.

This, however, may easily arise, owing to the mines drawing water from a much larger surface, than the area of country directly overlying them, which, as being the deepest spots for a considerable distance, they may readily be conceived to do.

To descend from the general theory of springs to the causes of their particular characters, I will first notice the circumstance of temperature.

Origin of  
thermal  
springs.

\* Vol. v. See also Arago on *Artesian Wells*, in the *Annuaire* for 1835, translated in *Jameson's Journal*.

† Bland in *Phil. Magazine* for 1832, p. 38.

‡ *Phil. Magazine*, New Series, vol. i., 1832, p. 287.

According to Von Buch\* all springs containing carbonic acid are more or less thermal, and Gustavus Bischof goes so far as to assert, that this remark extends universally to springs of constant temperature†.

The smallest difference, he says, between the warmth of the springs of a country and that of the soil, is never less than  $2\frac{1}{4}$  degrees of Fahrenheit.

But I have already observed, that Bischof generalized on too narrow a basis, when he inferred from the observations quoted in his memoir the universality of such a law.

It is one indeed directly at variance with the tenour of observations made within the tropics, which seem to show, that in warm climates the mean temperature of the atmosphere is even higher than that of the perennial springs‡.

And if the remark be limited to colder regions, many anomalies require to be reconciled, and a much more extensive series of observations gone through, before it can be decided, whether this augmentation of temperature be the result of a general law, or of local circumstances. Thus, for example, if, as Humboldt and others have supposed, the excess of temperature in springs over the atmosphere increases with the latitude, then indeed the temperature assigned by Bischof as the minimum in the case of those near Andernach, in lat.  $50\frac{1}{4}^{\circ}$ , squares very well with the rate of progression indicated by observations, on the springs of Paris in lat.  $49^{\circ}$ , and those of Berlin in lat.  $52\frac{1}{2}^{\circ}$  §.

For at Paris the mean temperature of the climate was found at  $51^{\circ}6$ , and that of the springs  $52^{\circ}7$ , the excess being  $1^{\circ}1$ ; whilst at Berlin the atmospheric temperature was  $46^{\circ}4$ , terrestrial  $50^{\circ}2$ , excess  $3^{\circ}8$ , indicating a rate of progression equal to about  $1^{\circ}8$  of temperature to  $1^{\circ}$  of latitude.

But, on the other hand, the accurate observations of Playfair have shown, that at Edinburgh, in a still higher latitude, viz.  $55^{\circ}58$ , the temperature of springs is identical with that of the atmosphere, so that the supposed progression would seem to be confined to a still higher latitude than this.

Neither are the observations of Wahlenberg in the Scandina-

\* Poggendorff's *Annalen*, vol. xii. p. 415.

† *Edinburgh New Phil. Journal* for April 1836.

‡ See Von Buch, on the Temperature of Springs, *Edinburgh New Phil. Journal*, October, 1828, or his work on the Canary Islands, p. 84, French translation; where he accounts for the fact, from the circumstance of the springs being derived from rain, which had fallen exclusively during the colder months, and which does not readily acquire, within the slowly conducting substance of the strata containing them, the temperature of the hotter portions of the year. See also Bischof's often quoted memoir, in which he disputes the general law, and supposes the tropical springs alluded to, to have been derived from high mountains, and therefore to possess a lower temperature.

§ Humboldt on Isothermal Lines, *Edinburgh New Phil. Journal*.



vian Peninsula \*, nor those of Kupffer on the Ural range †, absolutely conclusive, as to the generality of the supposed law even in the high latitudes to which they refer.

The elevation of temperature may, for ought we know, be confined to the neighbourhood of uplifted chains of mountains ; it may be a consequence of those great natural events to which are owing the disturbances there experienced ; and consequently it may not extend to the great plains of Russia or Siberia, where no such local influences exist. Or if it should be found on further examination to be general in northern latitudes, it will still remain to be discussed, before referring it to central heat, whether the phænomenon may not depend upon the cause suggested by Von Buch in the memoir before referred to, namely, that the transmission of temperature through the earth chiefly takes place by the infiltration of water, a cause which, of course, ceases to operate below 32°.

Granting, however, that the springs, which Bischof has noticed, owe their excess of temperature in part to a generally pervading cause of heat, we have still to account for the enormous differences in this respect existing between one and another, and this is what I now propose to consider.

The degree in which they exceed the mean of the climate is dependent, amongst other circumstances, on the elevation on the earth's surface at which they issue.

Von Buch ‡ has given various instances of springs, belonging to the same district, but bursting out at different heights, which, though they may correspond in mineral and gaseous impregnation, differ materially in temperature, the lowest being the hottest.

Boussingault§ also states, that in the littoral chain of Venezuela the temperature of the thermal springs is less in proportion as their absolute height is greater.

Thus the warm spring of Las Funcheras near Puerto Cabello, which approaches the level of the sea, possesses a temperature of 97° cent. That of Manaro, at a height of 476 metres, has only one of 64° ; and that of Onoto, at 702 metres, only 44°·5.

This regularity, however, does not extend to hot springs in immediate contact with volcanos. Von Buch || conjectures, that the heat of such springs is derived from the carbonic acid which impregnates them, and which possesses itself a high temperature, as having proceeded from a great depth.

\* *Annals of Philosophy*, vol. iv. 1814, translated from Gilbert's *Annalen*.

† Kupffer in *Edinburgh New Phil. Journal*, vol. xxii.

‡ Poggendorff's *Annalen*, vol. xxii.

§ *Annales de Chimie*, 1831.

|| Poggendorff's *Annalen*, vol. xii. p. 415.

This, however, is controverted by Bischof\*, who shows clearly that no considerable augmentation could have arisen from such a cause.

Brongniart, in an article† in the *Dictionnaire des Sciences Naturelles*, has pointed out, that the temperature of thermal springs is regulated by the nature of the rocks from which they issue.

The hottest are those associated with recent volcanos, next those proceeding from extinct ones, or from primary rocks, and lowest in the scale such as are connected with younger formations; and though this rule may admit of exceptions, yet it seems to hold good in the majority of cases.

Geological  
position of  
thermal  
springs:

Now this observation of Brongniart will be found to harmonize, and to point the same way, with the conclusions to which I have myself been conducted by the study of thermal springs, a summary of which will be found in an article in the *London Review* for 1829, and in a memoir inserted in the *Edinburgh New Philosophical Journal* for 1831.

In these publications I have attempted to show, that by far the majority of thermal waters arise, either from rocks of a volcanic nature, from the vicinity of some uplifted chain of mountains, or lastly, from clefts and fissures caused by disruption.

In many cases, indeed, all the above circumstances are seen combined; for the same spring may at once issue from the midst of volcanic products, be situated at the foot of an uplifted chain, and proceed out of a chasm or fissure; so that, in classifying springs according to the above plan, we should find many perhaps possessing an equal claim to a place in all the three divisions.

This circumstance, however, although it might prevent our adopting the above distinction, as the basis of a classification of mineral springs, only adds strength to the argument in favour of a common origin being ascribed to them.

1st, near  
volcanos.

With respect to the first of these classes of springs, I have pointed out in a subsequent paper‡, that they may be placed under two heads, namely, first, those impregnated with gases which are derived from volcanic energy, and probably owe their origin to processes now continuing; and secondly, those which, from the absence of such accompaniments, seem to be nothing more than reservoirs of water heated by coming into contact, with a mass of rock, retaining some of the warmth it had acquired from the volcanic operations of an antecedent period.

The springs of Mount Dor, of Hungary, and some of those in

\* On Hot and Thermal Springs, *Ed. Journal*, 1836.

† EAUX.

‡ On a Spring at Torre del Annunziata in *Edinb. New Phil. Journal*, 1835.

the Andes, are instances of the former ; those of Ischia, noticed by myself, and those enumerated under the head of “ *simple thermal waters*,” by Anglada\*, and by Fodéré†, which latter are called in the country *chaudons*, and spring from below beds of gypsum, I consider to be illustrative of the latter.

The connexion of thermal waters with uplifted chains will best be seen by coupling this description of springs with the carbonated ones which usually accompany them, and which, from the similarity of their mineral, and still more of their gaseous constitution, no less than that of their geological position, seem plainly referable to the same system of causes.

Gustavus Bisehof, in the work so often quoted, has enumerated nine of these groups existing in different parts of Europe, alike impregnated with carbonic acid and soda. These are

1. The springs of the Eifel and Siebengebirge.
2. Those of the Westerwald and Taunus.
3. Of the Habichtswald, Meissner, Vogelsgebirge, and Rhongebirge.
4. Of the Fichtelgebirge.
5. Of the Erzgebirge.
6. Of the Bohemian Mittelgebirge.
7. Of the Riesengebirge in Silesia.
8. Of Auvergne and the Vivarais in France.
9. Of the Pyrenees‡.

Now it is to be observed, that of the above groups two, namely, the mineral springs of the Rhine Province, and those of Central France, belong to our antecedent class ; and that a portion at least of the sixth group is allied to the same, since the mineral waters of Toeplitz and Bilin are manifestly in connexion with the porphyry-slate, and the volcanic products of the Mittelgebirge, and those of Franzensbad, with the little volcanic crater and scoriform lava of the Kammerburg in its immediate neighbourhood.

With regard to the remainder, it may be remarked, that the existence of trappean or porphyritic rocks in the vicinity of many of them, is a circumstance strongly corroborative of their volcanic origin, and consequently of the operation of forces capable of uplifting the mountains in their vicinity.

It is likewise a negative proof of the same connexion, that no mineral springs of such a constitution are found on the continent of Europe, considerably north of the limit to which basaltic and

2nd, near  
systems of  
elevation.

\* Vol. ii. p. 170.

† *Voyages aux Alpes maritimes*, p. 155.

‡ We have seen, however, that Anglada denies the existence of carbonic acid in these waters.



trappean rocks extend, a limit which nearly coincides with the line of elevation passing through the centre of Germany.

It is certain, at least, that throughout those vast tracts of comparatively level country, which constitute the greater part of Northern Russia, Poland, and Prussia, neither basaltic rocks, nor thermal or carbonated springs have been noticed, whilst both the one and the other appear to become more and more abundant, in proportion as other indications of volcanic action appear.

The above-mentioned groups however constitute but a small part of those distributed throughout Europe.

I have already shown, that the thermal springs of the Alps often contain alkali, and the occasional absence of that ingredient ought surely not to place them in another class, when their gaseous impregnation and other phenomena coincide with those included under it.

There is therefore a group of thermal springs manifesting itself, both in the central chain of the Alps, as at Baden in Argau, Schinznach, Pfeffers, and Louèche, and on its western and southern flank, at Aix in Savoy, St. Didier, Bonneval, and at Acqui and Coni in Piedmont.

Nor are other chains of mountains destitute of their own appropriate systems of thermal and carbonated springs. To mention one of the least known, that indefatigable geologist, Dr. Boué, who has lately been exploring the provinces of European Turkey, informs me, that in Servia and Bosnia, there exist acidulous and saline mineral waters, like those of Nassau, and that in the western part of the former province, as well as in Bulgaria, a line of hot springs with sulphuretted hydrogen, and probably azote, makes its appearance.

The line begins at Mehadia in the Bannat, and continues to the south of Nissa. The great masses of travertin found in the neighbourhood denote, that carbonic acid was formerly evolved in large quantities.

South of the Balkan and Orbelus, is a line of hot springs, running from east to west, which also contain sulphuretted hydrogen. Their highest temperature is 58° R. (162° Fahr.).

Eruptions of trachyte and dolerite seem to have been the precursors of the bursting out of these latter springs.

Without extending our inquiry into other parts of the globe, where it would be easy to point out groups of mineral springs similarly constituted, let us consider how the latter stand related to the mountains in the vicinity of which they lie.

It would seem, as I have remarked in the memoir on Thermal Waters before referred to, that a large proportion of them are placed near the line at which the elevation of the chain appears

Relation  
of these  
springs to  
the rocks  
contiguous.

to have commenced; but that when situated near to its axis, they generally occur in some deep valley, and consequently at a comparatively low level.

This is the case with Barcege and Cauterets in the Pyrenees, and with St. Gervais in the Alps, which latter, as M. Delarive\* had many years ago observed, is situated exactly on the spot which, of all others, unites most completely the conditions, of approaching in the nearest degree to the centre of the chain, and being at the same time least elevated above the level of the ocean.

But Professor Forbes, in an interesting memoir to which I have already had occasion to refer†, points out other circumstances of physical constitution, which seem to characterize the greater part, at least, of springs of this description.

He has shown, by an extensive induction of particulars, that the thermal springs of the Pyrenees, for the most part gush out from the vicinity of intrusive rocks, such as granite, serpentine, greenstone, and the like; moreover, that the structure and position of the stratum through which the latter have been thrust, are both of such a nature as to afford indications of violence.

Several of these thermal waters he has even traced, rising exactly from the line of junction between the granite and the stratified rock.

And this brings me to the consideration of the third circumstance alluded to as characterizing thermal waters; I mean their connexion with faults or dislocations.

This mutual relation is illustrated by the case of the Carlsbad springs, according to the description of them given by Von Hoff‡.

They are described by him as issuing from the bottom of a narrow glen, bearing in itself the evidences of some great natural convulsion.

It lies nearly at right angles to the valleys of denudation that exist in the immediate neighbourhood; it is more narrow and more precipitous than the latter; and, as Von Hoff states, the granite which forms the fundamental rock, is overlaid by a breccia, made up of fragments of this rock cemented together by a siliceous paste, which is in great measure covered over by the calc. sinter deposited at present by the springs, but in one side of the valley protrudes itself, and appears above it.

This breccia Von Hoff attributes to the spring, which in former times, like those of Iceland, may have deposited siliceous matter; but as, on a recent visit to Carlsbad, I could perceive no kind of breccia that bore the appearance of having been cemented by the materials of a thermal water, I am disposed to doubt this

3rdly. Contiguous to extensive faults or dislocations.

\* *Bibliothèque Britannique.*

† *Phil. Trans.* 1836.

‡ *Geognostische bemerkungen über Karlsbad.* Gotha, 1825.

part of Von Hoff's statement, although able to confirm the general truth of his representation.

Stift, in his geological description of the neighbourhood of Wiesbaden\*, remarks, that the following facts have been observed by himself relative to the springs of the Nassau territory.

1st. That they follow distinctly six lines, and thus evince a determinate direction.

2nd. That the rocks in their neighbourhood manifest evident changes in the direction and inclination of their strata, especially saddle-shaped elevations, often accompanied with fractures.

3rd. That in many places the adjacent rocks themselves appear altered, and are more friable than elsewhere.

In my memoir on Thermal Springs already referred to, I have pointed out several instances of the same connexion, between the existence of evidences of dislocation in the strata, and the bursting out of thermal springs, as occurring along the line of the Pyrenean chain, as at Aleth, Rennes, and Campagne, and still more remarkably at St. Paul de Fenouilhede, on the road from Carassone to Perpignan, near the town of Caudiez, all in Roussillon. The same fact is still more strikingly illustrated, by the structure of the country at St. Vincent's rocks, as described by Conybeare and Buckland†, and at Matloek, as long ago pointed out by Whitehurst‡; for, since the rocks from which the thermal waters in these two instances proceed, are stratified, the inference, to which the mere inspection of the localities conducts us, is confirmed by the unconformable disposition of the strata themselves; we not only observe springs gushing out from a narrow and precipitous cleft, but we find on examination the strata tilted up and disarranged, in a manner which implies that some violent action must have taken place. Mr. Murchison and Mr. Lyell§ have also remarked, that the hot spring of Aix in Provence lies contiguous to some remarkable dislocations of the strata.

We must not, indeed, strain too far our inferences from this one circumstance; for it is probable, as has lately been shown by Mr. Hopkins||, that natural springs, of whatever temperature, have their origin very commonly in fissures, which appear owing to dislocations or disturbances in the strata.

The latter, however, exhibit no evidences of violence, at all comparable to those afforded by the great natural chasms, to

\* In Rullman's *Wiesbaden*.

† *Geological Transactions*, vol. i. New Series, "On the South West Coal Field of England."

‡ Whitehurst's *Theory of the Earth*, 1786.

§ *Edinburgh New Philosophical Journal*.

|| *Cambridge Philosophical Transactions*, 1836.



which I have principally appealed, exhibited at Carlsbad, Matlock, and Clifton.

And it is only in the last of these instances, where, fortunately for our argument, the evidence is of a more decisive character than in the rest, that we are unable to strengthen it by other collateral proofs, derived from the presence of intrusive rocks, or the general appearance of the surrounding country.

In the other examples cited, I might have been indisposed to build upon this one fact, as a decisive proof of violent action having taken place in the locality, had not the probability of such events having occurred, obtained confirmation from other circumstances that had been pointed out.

Thus at Carlsbad, the existence of volcanic products both to the east and west of the spot, as well as the propinquity of the spring itself to a mountain range, which doubtless owes its elevation to volcanic forces, together strengthen the inference which the particular character of the locality would dispose us to adopt.

It appears then, that the geological position of thermal waters in general leads to the conclusion, that they are connected with certain volcanic processes going on near the places in which they occur; but it must be at the same time admitted, that in a few special cases a high temperature is imparted to the springs of a district, by causes of a more local and superficial character.

Theories of thermal springs.

Local causes.

Thus Kastner\* states, that in the Westerwald, between Marienburg and Stockhausen, the burning of brown coal underground has caused so great a heat in the contiguous rocks, as to give rise to several warm springs, which are characterized by the presence of acetic and succinic acids, both probably derived from the slow distillation of lignite.

Setting aside, however, these comparatively rare and special cases, let us next briefly consider, how far the facts detailed in the preceding part of this Report, will assist us in explaining the cause of that exalted temperature, which thermal springs in common with other volcanic phenomena exhibit.

General causes.

With respect to this question, a recent memoir by Professor Bischof of Bonn†, may be quoted, as disposing successfully of the hypotheses, in which certain chemical processes going on at the present time near the surface, such, for example, as the decomposition of pyrites, were appealed to, as capable of producing the heat which these springs possess. He has also said enough respecting another hypothesis, that of Anglada, who attributes

\* *Archiv*, vol. xvi. † *Edinburgh New Philosophical Journal*, April, 1836.

the heat of springs to the action of electricity. This mighty agent is doubtless concerned in many of the changes which go on in rocks, but before we attribute to it the production of that steady heat which resides in certain springs, we ought to consider, what peculiar disposition of strata would be necessary to give rise to it, what evidence there is of such a disposition existing, and why, if it exist at all, it be not more general, and thus render the occurrence of hot springs less a local phenomenon.

None of these questions having been entered upon by An- glada, it would be superfluous at present to proceed to a formal consideration of his hypothesis.

Neither need I dwell upon any such hypotheses, as are founded on assumptions, which either seem contrary to acknowledged principles of physics, or which would be rejected by the general voice of men of science as absurd and fanciful.

Thus I shall do no more than allude to the mode, in which Aristotle somewhere accounts for the high temperature of springs, by supposing, that as the figure of the earth is spherical, the solar rays penetrating its substance, ought to meet in the centre, as in the focus of a burning glass, and thus produce there an intense degree of heat.

Neither shall I labour to refute the idea of Keferstein, that thermal springs are merely the result of, what he is pleased to call, the respiratory process of the earth, resting, as that opinion does, upon the assumption, that the globe itself is an animated body, a position, which I am loth seriously to attack, not knowing in what precise sense his language is to be interpreted.

But there remain two theories with respect to the origin of thermal springs, that seem to deserve a more attentive consideration.

Chemical  
theory  
stated.

The former of these supposes them to arise from chemical processes carried on within the earth, processes, however, which possess nothing, in common with those witnessed on or near the surface, except the circumstance of being attended with an absorption of oxygen.

If it be further demanded of the advocates of this theory, what particular chemical processes are alluded to, they will probably reply\*, that a competent explanation of the phenomena

\* They ought however carefully to distinguish, between that which appears to be a direct inference from observed facts, and what at the most can advance no higher claim, than of being a plausible conjecture. The general occurrence of volcanos in the neighbourhood of the sea, and the constant disengagement of aqueous vapour and of sea-salt from their interior, are facts, which establish in my mind a conviction, that water finds its way to the seat of the igneous operations, almost as complete, as if I were myself an

would be afforded, by the supposed oxidation of the bases, of those alkalis, earths, and metallic oxides, which are found to constitute the crust of the globe, through the agency, first of water, and afterwards of atmospheric air.

Such, in a few words, was the theory which I adopted, to account for the phænomena of volcanos\* in a work published on that subject in 1826†; and to the same, after a mature, and, I trust, an impartial review of the question, I am still disposed to adhere, in preference at least to any other.

In an article entitled GEOLOGY, in the *Encyclopædia Metropolitana*, I have endeavoured to reply to all the arguments that had been subsequently urged against my views; and if I have not noticed every individual objection, it has only been, because the same difficulties were brought forward again and again by different persons, often without any allusion being made to the answers, which I had given to similar ones before.

The latter theory, discarding all chemical operations whatsoever, regards thermal springs as arising merely from the internal heat of the globe, and consequently as possessing a temperature high, in proportion to the depth from which they have themselves proceeded.

Theory of  
central  
heat.

For, as the temperature of the earth augments, as we descend, on the average, about  $1^{\circ}$  of Fahr. for every 100 feet, it is evident, that, if the increase be progressive, water would arrive at its boiling point at a depth not exceeding three miles, and there is no difficulty in understanding, that it should retain the greater part of that exalted temperature, when once the channels and passages in the rock, through which it reached the surface, were thoroughly penetrated by the heat.

The theory just mentioned is sanctioned by the high authority-witness of another Phlegethon discharging itself into the bowels of the earth, in every volcanic district, as in the solitary case of Cephalonia.

Nor, as I shall afterwards attempt to prove, is the access of atmospheric air to volcanos more questionable, than that of water; so that the appearance, of hydrogen united with sulphur, and of nitrogen, either alone, or combined with hydrogen, at the mouth of the volcano, seems a *direct* proof, that oxygen has been abstracted by some process or other from both.

Having satisfied our minds with regard to the *fact* of internal oxidation, we naturally turn to consider, what principles can have existed in the interior of the earth, capable of abstracting oxygen from water, as well as from air; and this leads us to speculate on the bases of the earths and alkalis as having caused it. But in ascribing the phænomena to the oxidation of these bodies, we ought not to lose sight of the Baconian maxim, that in every well-established theory, the cause assigned should be, not only competent to explain the phænomena, but also known to have a real existence, which latter cannot be predicated of my alkaline and earthy metalloids in the interior of the earth.

\* *Description of Active and Extinct Volcanos.* London, 1826.



rity of Laplace, and has also received the support of many modern naturalists.

Professor Bischof\*, in adopting it, has undertaken in a late paper first of all to refute the opposite hypothesis, but in attempting so to do, has, I conceive, mistaken the views of its advocates.

Thus he quotes an experiment of his own, in which the combustion of 15 grains of sodium, in water containing a quantity of sulphuric and muriatic acid, such as would be adequate to form the saline matter present in a particular thermal spring, raised the temperature of 1000 grains of water scarcely  $3^{\circ}$ ; and this he alleges as a proof, that the heat cannot have arisen from any process of oxidation in which sodium acts a part.

But under either view of the subject, the increased temperature of the spring must be attributed to that of the contiguous rocks, the only question being, do these rocks derive their high temperature from a central fluid mass, or from chemical processes taking place generally in the interior of the globe?

Having discussed this question at length elsewhere, I will at present confine myself to remarking, that the supporters of Bischof's views ought to be able to explain to us, why thermal springs are of local occurrence, and most frequent in proportion to the frequency of other indications of igneous activity; and if these latter indications are assumed to be themselves nothing more, than the result of the contraction of the earth's crust upon its internal fluid contents, why that contraction should be always accompanied with those exertions of explosive energy which we witness in volcanos, and those emissions of gas which are common to both.

They should also explain to us, why primary rocks, traversed as they so frequently are with fissures of all descriptions, should not in every part of the world, and in every kind of situation, give rise to hot springs, by evolving steam from their interior, and why they never appear to give issue to that class of thermal waters, which I have noticed in Isehia as being unaccompanied with gaseous products, and which therefore I suppose, to be purely the result of the infiltration of water to spots in the interior of the earth retaining a high temperature.

In order however duly to appreciate the degree of support, which the chemical theory of thermal waters appears to derive from the nature of the gases which accompany them, I shall next propose to consider in detail the manner, in which these elastic fluids may severally be supposed to have been generated.

\* *Edinburgh Phil. Journal* for April 1836.

The carbonic acid, which is so frequent an accompaniment of thermal waters, is explained by Bischof \*, as deriving its origin from the calcination of earthy carbonates by the heat beneath; and to this view there seems to be no objection, provided only we admit, that a portion of water is present, without which, as Faraday has shown, no disengagement of carbonic acid would take place under the influence of even a great heat.

Origin of  
the carbonic  
acid evolved  
from  
springs.

But that the amount of carbonic acid emitted bears some relation to the igneous or eruptive agency heretofore exerted, will appear by a mere enumeration of the localities in which this gas most abounds.

Passing over its copious emission in the neighbourhood of active and extinct volcanos, I may notice the observations of Hoffman†, who has stated, that the carbonic acid so abundantly evolved at Pymont, rises out of what he describes as a circular valley of elevation, caused by the heaving up of the rocks in all directions round this central point.

Sometimes also the evolution of carbonic acid is connected with faults, as has been observed by Professor Phillips with respect to the carbonated or petrifying springs of Yorkshire‡.

So general indeed is the distribution of calcareous rocks in the older, as well as the more modern formations, that I do not see the force of the objection started by Berzelius to the chemical theory of volcanos, in a notice with which he some years ago honoured the work I had published on that subject§, in which he says, that it fails in accounting for the extrication of carbonic acid gas, as a consequence of volcanic action.

For my own part, inasmuch as an intense degree of heat is the immediate effect of these operations, and as rocks containing carbonic acid in a fixed state are so generally diffused, I should conceive that the extrication of this gas would have been anticipated to be a natural result of the process; unless, indeed, by those theorists, who, maintaining the contrary hypothesis in its simplest form, refuse even to admit that water has had any necessary share in the phenomena.

The evolution of nitrogen from springs has been discussed by Berzelius, Anglada, and others.

Origin of  
the nitro-  
gen.

Berzelius|| supposes it to arise from the decomposition of the organic matter which these waters contain, whilst Anglada¶

\* *Vulkanischen Mineralquellen*, p. 255.

† On Valleys of Elevation, *Edinburgh New Phil. Journal*, October, 1830.

‡ See my memoir on Thermal Springs already referred to.

§ *Jahresbericht*, vol. vii. p. 352.

|| "Analyse des Eaux de Carlsbad," *Ann. de Chim.*, vol. xxiii.

¶ *Mémoires pour servir*, &c.

refers it to the atmospheric air present in them, the oxygen of which is absorbed by the sulphur found along with it.

The theory of Berzelius may perhaps suit those cases, in which the quantity disengaged is small, but can scarcely be extended to others, in which it is more considerable.

No amount of organic matter, that can be supposed to exist in the thermal water, could produce a constant supply of nitrogen, continuing for hundreds and probably thousands of years, equal on an average to 222 cubic feet in the 24 hours, as at the hot spring of Bath.

It would also have seemed needless to remark, had not the circumstance been overlooked by some who have commented upon this phænomenon, that the decomposition of organic matter would generate other gases never met with amongst thermal springs, especially carburetted hydrogen, which is actually found to accompany nitrogen in cases where the latter proceeds from organic matter, as was determined, with respect to the gas that renders buoyant the floating island of Derwentwater, by Dr. Dalton.

The explanation of Anglada seems to me only faulty in not being sufficiently general.

Sulphur no doubt is one of the principles by which the oxygen is abstracted, but it does not seem probable that it should be the only one; and the case of Bath alone serves to show, that it is sometimes absent altogether from waters, where the evolution of nitrogen is most abundant.

In short, the only direct inference, that seems deducible from the fact of the copious evolution of nitrogen from thermal waters is, that certain processes, occasioning the abstraction of oxygen from common air, are going on in the interior of the earth.

This inference remains the same, whether we suppose the nitrogen emitted, to consist merely of that carried down by the atmospheric waters, by which the thermal spring is maintained, or to be the residue of the atmospheric air, that had found its way into cavities, where these processes are taking place.

Both explanations may occasionally be true; but whichever one we choose to adopt, the ultimate fact is still as before, namely, that a quantity of air, which, if derived from the atmosphere, contained originally  $\frac{1}{5}$ th of its volume of oxygen, and if from atmospheric water, would contain nearly double that amount, returns to the surface, often with scarcely  $\frac{1}{10}$ th, and at most with not more than  $\frac{1}{10}$ th, of this latter ingredient.

That atmospheric air does find its way into the interior of the



globe, and probably pervades every portion of its solid contents, is a fact, of which a little reflection will convince us.

Independently of, the cracks and fissures, by which the earth's crust is everywhere intersected, the large cavities it so frequently envelopes, and its general porosity and permeability to water containing air in solution, the solid strata themselves have the property, as has been shown by Saussure\*, in various degrees, of absorbing oxygen and nitrogen gases; though it is to be remarked, that by a curious provision of nature, apparently designed to forward the process of internal oxidation, the two gases are absorbed, not in the proportion of five to one, but in nearly equal ratios.

Professor Meinecke of Halle† is the only person, so far as I know, who has availed himself of this, as a principle on which to explain other phenomena; and his remarks, owing to certain loose and fanciful speculations interwoven with them, have not yet obtained much attention.

Nevertheless, if it be true, that air pervades even the solid portions of our globe, down at least to a considerable depth, it seems not absurd to imagine, that it may suddenly be augmented by an increase of atmospheric pressure above, or diminished by processes taking place in the interior of the earth.

Such, in the main, are the views of Professor Meinecke, who imagines the amount of air retained in the interior of the earth, to be in a state of constant oscillation, and thus, reacting upon the atmosphere above, to be one of the causes of the variation of the barometer. He even attributes, to an extraordinary absorption of air within the earth, a remarkable sinking of the barometer, which took place without any other assignable cause at Christmas 1821.

The sulphuretted hydrogen, which so many springs contain, has been attributed to the action of organic matter upon alkaline and earthy sulphates; and M. Henry of Paris‡ has cited an example, where a spring, which at its source contained sulphates of soda, magnesia, and lime, but no sulphuretted hydrogen, was found to have acquired a trace of that gas, at the expense of its sulphuric acid, after mixing with the water of a washing place.

Origin of  
the sul-  
phuretted  
hydrogen.

It seems probable, that the hepatic smells, which occur in the waste and stagnant waters of towns, sometimes arise from this

\* *Bibliothèque Britannique*, vol. xlix. p. 319.

† *Schweigger's Journal*, vol. viii. 1823.

‡ *Journal de Pharmacie* for 1827, p. 493.

cause; and M. Brongniart\* attributes the sulphuretted hydrogen present in the mineral water of Enghien, to the action of organic matter upon beds of gypsum belonging to the Paris Basin.

But no one would attempt to explain in this manner, the sulphuretted hydrogen contained in many thermal waters, still less that evolved from volcanos; a phenomenon, which seems to me to supply just the same evidence of the decomposition of water within the earth, which the emission of nitrogen affords of the abstraction of oxygen from atmospheric air. And if it should be established, as many observers of volcanic phenomena have thought probable, that the sulphur, which finds its way to the surface by the agency of volcanos, is always held in solution either by oxygen or hydrogen gases, the enormous quantity of either principle which is sent back to the atmosphere in conjunction with this Inflammable, may be in some measure appreciated from one circumstance alone, namely, from the vast beds of volcanic sulphur accumulated in many parts of Italy, and still more remarkably in Sicily.

Professor Phillips is even of opinion, that the origin of the mineral impregnation of the waters of Harrogate is to be ascribed, to the chemical effects specially exerted along the line of a subterranean disturbance, which he has traced in the vicinity of these springs; and Mr. Murchison has been led to similar conclusions, with respect to the sulphureous spring of Llanwrtyd, by the geological structure of that locality.

Origin  
of salt  
springs.

The only remaining class of springs, that requires further notice, is that which contains common salt, and the other ingredients of our present seas.

The origin of these springs from masses of salt or muriatiferous clays, produced by the evaporation of sea-water, or of lakes of similar composition, would seem sufficiently obvious; and Mr. Lyell† has even attempted to explain the manner, in which a deposition of salt may be taking place at the present day from the waters of the Mediterranean, so as eventually to build up a bed of rock salt underneath it.

But although the law of the increasing specific gravity‡ of water, in proportion to the degree of its saline impregnation, would favour the process of deposition, when once it had commenced, by keeping up a constant supply of the strongest brine near the bottom of the sea, we still seem to want some agent, for

\* *Dict. d'Hist. Nat.*, art. EAUX.      † *Principles of Geology*, vol. i. p. 297.

‡ See a curious paper on the increasing strength of a brine well in proportion to its depth, in the *Phil. Magazine*, vol. iv. p. 91.

bringing about a separation of its solid contents, from a fluid so far removed from saturation, as the water of our present seas is found to be.

Now a submarine volcano, or any other independent cause, producing a high temperature in any part of the bed of the ocean, might supply this desideratum; it would separate the salt from that portion of the water which came most within its immediate influence, converting the fluid into vapour, which, in a highly compressed condition, we may imagine to be interposed between the bed of salt in the act of forming, and the body of the superincumbent ocean.

That volcanic action may have had some share in the formation of beds of salt, is no new idea, and is immediately suggested by the almost constant association, of sulphuric salts, and especially of gypsum, with the former.

Thus Von Buch\*, remarking on the connexion of rock-salt and brine springs with anhydrous gypsum at Bex in Switzerland, attributes them both to direct sublimation from the interior of the earth, the common salt being accompanied by sulphuretted hydrogen, which, by its gradual conversion into sulphuric acid, had given rise to the formation of sulphate of lime.

That rock-salt is sometimes sublimed from the bowels of the earth we know by an examination of volcanos; and where common salt is found abundantly in thermal springs which are of volcanic origin, and issue from primary rocks, as is the case with that of St. Nectaire in Auvergne, and possibly that of Wiesbaden in Nassau, it seems but reasonable to attribute its occurrence to a similar cause.

Proust† even has stated, that the salt mine of Burgos in Spain lies in the crater of an extinct volcano; and though he may possibly be mistaken as to this exact point, still such a notion would hardly have arisen, had not the beds been in a manner surrounded by volcanic products.

Without, however, proposing so bold an hypothesis as that of sublimation, to account for the production of salt beds in general, we may perhaps see reason to suppose, that volcanic heat has in many cases caused their deposition, and that the sulphates which accompany them have arisen from the sulphuretted hydrogen, which is at the present day an ordinary effect of volcanic processes.

In my memoir on the Lake Amsanctus‡, I have attempted to trace the connexion, between the operations of volcanos, the

\* Poggendorff's *Annalen*, 1835.

† *Journal de Physique*.

‡ Published by the Ashmolean Society, Oxford 1836.



emanations of carbonic acid, and the formation of beds of rock-salt; on the present occasion it may be sufficient to quote the following brief summary of the points therein insisted on.

Volcanos give out .....	Sulphuretted hydrogen, sal ammoniac, boracic acid, muriatic acid, steam;
And cause .....	Deposits of sulphur, of sulphuric salts, of muriatic salts, &c.
Moffettes, connected geographically with volcanos now in action or extinct, give out	The same principles;
And cause .....	Deposits of sulphur and of sulphuric salts.
Many tertiary clays, some of which are connected in a geographical sense with volcanos .....	Contain beds of sulphur, of earthy sulphates, and of common salt.
Most salt formations are associated with .....	Beds of gypsum.
Some with .....	Sulphur.
Others with .....	Sal ammoniac.

Works on  
mineral  
waters.

I shall now conclude, by enumerating a few of the newer works on mineral and thermal waters that appear to afford the most original and important information on the subject, considered in a scientific point of view.

On English medicinal springs, Dr. Scudamore\* has published a good practical treatise, and with the assistance of Mr. Garden, has undertaken to give an analysis of the more important ones which this country possesses. His work, however, is more adapted for practical physicians than for men of science, as he has limited himself exclusively to those mineral waters which already possess a reputation as medicinal agents.

Professor Anglada† of Montpellier has published a very detailed and elaborate description of the thermal springs of the Eastern Pyrenees, in which he has investigated in particular, the

\* *Treatise on the Composition and Medical Properties of the Mineral Waters of Buxton, &c.* Second Edition. London, 1833.

† *Mémoires pour servir à l'Histoire générale des Eaux minérales sulfureuses*, 2 vols. 1827; and *Traité des Eaux minérales des Pyrénées Orientales*, 2 vols. 1833.

condition in which the sulphureous principle of these waters exists, and that peculiar organic matter which is associated with the waters.

Having already commented upon these points, I need only further remark, that I consider the work in general a most valuable addition to our knowledge.

M. Longchamp, who was expressly engaged by the late French Government to examine the mineral waters of that country, has completed his report on those of Vichy\*, which appears to be drawn up with considerable care, but has been arrested in the further prosecution of the design by the overthrow of the Bourbon dynasty. In a little work, entitled "*Annuaire des Eaux Minérales*" for 1831, he has given a sketch of the principal springs of the Pyrences and of others in France, which may be consulted to advantage.

The work of Alibert†, though it bears the name of a distinguished medical writer, is evidently designed as a popular compendium, and therefore hardly comes under review on the present occasion; nor am I aware of any other work of scientific interest on this subject, that has recently appeared in the French language.

In Germany works on mineral waters abound; but perhaps the most important is one published by Professor Bischof‡ of Bonn in 1826, relative to the mineral springs of the Rhine province and others of similar constitution, replete with valuable information, and important general views.

In criticising some of the latter, I have all along been conscious of the risk I incurred of being myself in error; nor should I, perhaps, have been tempted to question them, had it not appeared to me, that inferences deduced from one particular class of mineral waters, ought to undergo the test of a severe scrutiny, before we permitted ourselves to apply them to the springs of other and distant regions.

Brandes§, with the assistance of Kruger, has published a very elaborate account of the waters of Pyrmont, and more recently a still larger work on those of Meinberg||, containing, not only a detailed description of the spring, but also of the topography, antiquities, and natural history of the neighbourhood.

But it would be endless to enumerate the various works on particular mineral waters, which have issued from the German

\* *Analyse des Eaux Minérales de Vichy*, 1825.

† *Précis Historique sur les Eaux Minérales*, 1826.

‡ *Die Vulkanischen Mineralquellen Deutschlands und Frankreichs*. Bonn, 1826.

§ *Beschreibung der Mineralquellen zu Pyrmont*, 1826.

|| *Mineralquellen zu Meinberg*. Lemgo, 1832.

press, and to which this general character seems to apply, that, although more frequently replete with mystical and absurd hypotheses, than works of the same class in England, they display in general greater research and a richer fund of scientific information.

Of general works, I may mention that of Scherer\* on the mineral waters of the Russian empire, which testify to this important fact, that there are neither thermal nor acidulated springs in any part of that vast tract, till we approach the mountains of the Caucasus and Oural, or the volcanos of Kamshatka.

Professor Schuster† of the University of Pesth has lately edited the elaborate work of Kitaibel on the Mineral Waters of Hungary, which will be found to contain a very detailed, and probably authentic, account of their properties.

But to the general reader the necessity of consulting these local authorities will soon be superseded, by the appearance of the treatise of Dr. Osann of Berlin‡, of which the two first volumes have been already published.

The first of these includes, a very complete sketch of the general views, entertained, with respect to the nature and constitution of mineral and thermal springs, and a *catalogue raisonné* of those best known, classified under their respective heads.

The second volume is occupied by a detailed description, of those of Germany, and some other contiguous countries, with copious references to original sources of information.

The whole appears to be compiled with great care and research, and promises, when finished, to be the most complete work extant on the subject.

Since the appearance of the first volume of Dr. Osann's work, Dr. Gairdner of Edinburgh has brought out a very compact, and useful Manual, in the English language, on the same subject§. A large portion of its contents indeed are evidently extracted from Osann; nor does it appear, that the author has drawn much from any stores of his own in the facts stated by him.

Nevertheless the multitude of details brought together, and judiciously arranged in this little volume, ought to secure it a place in every scientific library; and the best proof I can fur-

\* *Versuch der Heilquellen des Russischen Reichs*. St. Petersburg, 1820.

† *Pauli Kitaibel Hydrographica Hungariæ*, edidit J. Schuster, Pesth, 1829.

‡ *Darstellung der bekannten Heilquellen Europa's*. Berlin, vol. i. 1829, vol. ii. 1832.

§ *Essay on the Natural History, &c. of Mineral and Thermal Springs*. Edinburgh, 1832.



wish of my own opinion of its merits is, that I conceived it to have superseded the demand for a distinct work on the subject, which I had for several previous years been preparing.

Indced I have been induced in some measure to modify the nature of this Report in consequence, having endeavoured to be most full on those points, which had been passed over by Dr. Gairdner, and in other instances supplying rather a comment upon the facts he had collected, than a mere recapitulation of their substance.

---

#### APPENDIX TO PAGE 42.

When mentioning the reported presence of oxygen in thermal waters, I ought to have added, that Fodéré, *Voyages aux Alpes maritimes*, states, that this gas was extracted, by boiling, from the water of Roccabigliera in Piedmont, in such quantities, and of such purity, as led him to believe, that a portion of deutoxide of hydrogen must have been present to occasion it. But so extraordinary a fact in the history of thermal waters, as this would be, requires further confirmation.

## Catalogue of

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours†	
						Water.	Gas.
<i>British Islands.</i> N. Lat. 55° to 51°. W. Long. 1 to 5°. Mean temp. reckoned about 49°.*	Bath.....	New red sandstone .....	Somersetshire	0	King's Bath 66°	King's Bath 28,339	King's Bath 22
	Bristol .....	Carboniferous limestone in a valley of disruption	Gloucestersh.	0	Hot Well 25	.....	.....
	Buxton.....	Ditto .....	Derbyshire ...	4	St. Anne's 33	St. Anne's 13,500	St. Anne's 41,60
	Bakewell .....	Ditto .....	Ditto .....	3	Bath Spring 13	.....	.....
	Stony Middleton	Ditto .....	Ditto .....	4	————— 14	.....	.....
	Taafé's Well.....	Coal strata .....	Near Cardiff, S. Wales	0	————— 21	.....	18·0
	Mallow.....	Carboniferous limestone	County of Cork, Ireland	0	Spa Well 23	.....	.....
<i>Germany.</i> N. Lat. 51° to 49°. W. Long. 24° to 32°. Mean. temp. reckoned about 50°.	Bertrich .....	Connected with extinct volcanos	Near Treves, Eifel	4	40	7240	.....
	Aix la Chapelle .	At the junction of clay slate, and carboniferous limestone	Lower Rhine Province	4	Kaiserquelle 85·5	.....	.....
	Borset .....	Ditto .....	Ditto .....	4	Mühlenbend 121·5	.....	.....
	Ems .....	Clay slate.....	Nassau .....	3	Rondeel 81	12,400	.....
	Wiesbaden .....	Chlorite slate .....	Ditto .....	3	Kochbrunnen 108	84,092	.....
	Schlangenbad ...	Clay slate.....	Ditto .....	4	Schachtbrunnen 27	21,328	.....
	Soden .....	Ditto .....	Near Frankfort on the Main	3	Gemeindebrunnen 20	.....	.....
	Kreutznach .....	Felspar porphyry .....	Lower Rhine Province	3	Münster am Stein 36	.....	.....

\* N.B. In this estimate of mean temperature, no allowance is made for height. It is evident, therefore, Buxton, Bakewell, &c.

† Where the name of the spring is not given, the number is understood to indicate the amount evolved

+ N.B. Where not otherwise specified, the spring alluded to in this and the next column is assumed to

*Thermal Springs.*

Gases evolved & their relative proportions one to the other.				Gaseous contents.		Solid contents.		
acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.		Total amount of ingredients in a pint of the water of the spring most strongly impregnated‡.	Nature of the more abundant and of the more active ingredients present.	According to
to 3.	3.5	96.5	Daubeny ...	Carbonic acid	C.In. 1.2	King's Bath 15	Mur. lime and magnesia; iron, (Iodine, Cuff.)	Phillips.
0.	8	92.	Ditto .....	Carbonic acid	3.750	Hot Well 5.95	Sulph. soda, mur. of lime	Carrick.
0.	0	100.	Pearson ...	Common air	0.375	St. Anne's 1.875	Mur. magn. and of soda ...	Scudamore.
0.	0	100.	Pearson ...	Carbonic acid	0.187	St. Anne's 1.875	Mur. magn. and of soda ...	Scudamore.
0.	0	100.	Pearson ...	Azote	0.580	St. Anne's 1.875	Mur. magn. and of soda ...	Scudamore.
0.	0	100.	Daubeny ...	.....	.....	Bath Spring 3.5	Sulph. of lime, mur. of soda	Daubeny.
0.	0	100.	Ditto .....	.....	.....	Warm Spring 2.0	Sulph. of soda and mag., mur. lime	Ditto.
0.	3.5	96.5	Ditto .....	.....	.....	1.2	Sulphate of magnesia .....	Ditto.
0.	6.5	93.5	Ditto .....	.....	.....	Spa Well 0.3	Carbonate of lime .....	Ditto.
.....	.....	.....	.....	Carb. acid, with a trace of sulph. hyd.	.....	18.267	Carb. and sulph. of soda; Lithia, potass	Funke.
0.	.....	69.5	Monheim ...	Sulphuretted hydrogen	.....	Kaiserquelle 31.95	Mur., carb., and sulph., soda; Sulphuret of sodium, phosph. soda	Monheim.
8.	2	80.	Daubeny ...	Carbonic acid	7.6	Muhlenbend 34.0	Mur., carb., and sulph., of soda; Lithia, strontian, fluoric acid	Ditto.
0.	0	0	Ditto .....	Nitrogen	19.0	Muhlenbend 34.0	Mur., carb., and sulph., of soda; Lithia, strontian, fluoric acid	Ditto.
0.	0	0	Ditto .....	Carbonic acid .....	.....	Kesselbrunnen 28.9	Carb., mur., and sulph., soda; Strontian, barytes, phosph. and fluoric acids.	Kastner and Struve.
3.	0	27.	Ditto .....	Ditto .....	.....	Kochbrunnen 57.59	Mur. of soda, lime, and potass; Bromine, manganese, and fluoric acid	Ditto.
.....	.....	.....	.....	Carbonic acid with a little nitrogen	.....	Schachtbrunn 6.0	Carb. of soda, muriate of soda	Fenner.
.....	.....	.....	.....	Carbonic acid .....	.....	Saltzquelle unter der Brucke 119.8	Mur. of soda; Potass, bromine	Schweinberg.
.....	.....	.....	.....	.....	.....	Theodorshall 87.9	Mur. of soda, lime, and magnesia; Potass, alumine, phosphoric acid	Prieger.

that a deduction must be made in all cases where the spring is placed above the level of the sea, as at

from all the thermal springs belonging to the locality.  
be the same, as that of which the composition is given.



## Catalogue of Thermal

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours	
						Water.	Gas.
Germany. N. Lat. 51° to 49°. W. Long. 24° to 32°. Mean temperature estimated at about 50°.	Wolkenstein ...	Mica slate .....	Saxony.....	13	33.5°		
	Wiesbaden .....	Ditto .....	Ditto .....	13	20.0		
	Carlsbad .....	Granite, in a valley of disruption	Bohemia .....	11	Sprudel 117.0	Sprudel 111,715	
	Bilin.....	Gneiss .....	Ditto .....	6	16.0	12,288	
	Töplitz.....	Volcanic porphyry .....	Ditto .....	6	Hauptquelle 71.0	77,250	
	Warmbrunn.....	At the foot of a granitic chain	Silesia .....	10	Trinkquelle 47.		
	Landeck .....	Gneiss .....	Ditto .....	14	Old Bath 35.5	12,960	
Germany.* N. Lat. 48° to 46°. W. Long. 26° to 30°. Mean temp. estimated at about 51°.	Wildbad .....	Granite .....	Wirtemberg...	13	Hauptquelle 47		
	Baden-baden ...	Ditto .....	Duchy of Baden	4	Ditto 96.4 F.†	12,033	
	Baden-weiler ...	Ditto .....	Ditto .....		30.5		
	Baden .....	Jura limestone.....	Austria .....	6	68.5	Hauptquelle 40,950	
	Gastein.....	Granite .....	Saltzburg Alps	30	66.5	4 principal springs 100,080	

\* This, however, is far above the mark with reference to the majority of springs enumerated, in consequence

† Within the same range of latitude as the above occur the following thermal springs, few of which as stated below, viz.

In Moravia.		In Styria.		In Carinthia.	
Uttersdorff .....	37.25	Doppelbad, near Gratz	32.75 F.	Töplitza .....	46.50
Töplitz .....	12.00	Romerbad, near Cilli ...	48.00	Montfalcone, near Trieste.	50.00
		Neuhaus, near Cilli.....	46.25		
				In the Tyrol.	
				On the Brenner .....	23.0

‡ Professor Forbes, *Philosophical Transactions*, part ii., 1836.

*Springs.* (Continued.)

Gases evolved and their relative proportions one to the other.				Gaseous contents.		Solid contents.		
Carbonic acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.		Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
					C.In.	Grs.		
4	2	98	Daubeny ...	Carbonic acid	.....	1·845	Carbonate of soda	..... Kuhn.
8	2	98	Ditto .....	Ditto	.....	4·03	Carb., sulph., and mur., of soda	Lampadius.
.....	.....	.....	.....	Ditto	11·85	49·6	Sulph. and carb. of soda ; <i>Strontian, manganese, fluoric and phosph. acids</i>	Berzelius.
.....	.....	.....	.....	Ditto	33·58	39·2	Carb., sulph., and muriate of soda ; <i>Lithia, potass, and manganese, phosph. acid</i>	Steinmann.
.....	.....	.....	.....	Ditto	2·4	15·6	Carb. and sulph. of soda ; <i>Phosph. acid</i> (Berzelius)	Ambrozzi.
0	5·3	94·7	Daubeny ...	Nitrogen	0·735	4·77	Sulph. and carb. of soda ; <i>Carb. of ammonia</i>	Tschortner.
2	0	100	Ditto .....	Carbonic acid	1·00	2·62	Sulph., and mur., of soda.	
				Sulph. hyd.	4·33			
2·00	6·44	91·56	Weiss .....	Carbonic acid	12·00	3·59	Mur., carb., and sulph., of soda	Sigwort and Weiss.
.....	.....	.....	.....	Nitrogen	79·25			
.....	.....	.....	.....	Oxygen	8·25	26·331	Mur. of soda, and of lime, sulph. of lime, silica	Otto and Wolf.
.....	.....	.....	.....	Carbonic acid	.....	1·7	Chiefly carb. of lime	..... Schmidt.
.....	.....	.....	.....	Ditto	.....			
.....	.....	.....	.....	Sulph. hyd.	3·33	1·076	Sulph., lime and magnesia	Schenk.
.....	.....	.....	.....	Carbonic acid	1·77			
.....	.....	.....	.....	Carbonic acid	.....	2·7182	Sulph. of soda, mur. of soda, and potass	Hünefeld.

of their high elevation.

have been sufficiently examined, but which exceed the assumed mean temperature (51°) of the climate,

<i>In Croatia.</i>		<i>In Hungary.</i>		<i>In Hungary.</i>	
Öplika .....	82·25	Ofen, or Bada .....	93·5	Szalathny .....	9·8
rapina .....	62·	Trencsin .....	53·0	Lucska .....	26·0
ulinczha .....	53·	Pöstheny, near Presburg...	95·75	Glasshütte, near Schumnitz	53·0
piker .....	73·25	Ribar, near Neusohl .....	27·80	Eisenbach, near ditto .....	53·0
ubicza .....	21·25	Altsohl, near ditto .....	32·75	Parad, near Erlau.....	35·0
		Stubcn, near Kremnitz ...	59·75	Szobrancz, near Unghoar .	19·25
		Gran .....	13·9	Budos, near Fünfkirchen...	86·75

## Catalogue of Thermal

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours	
						Water.	Gas.
France. From Lat. 51° to 50°. Long. 1° to 5°. Assumed mean temp. 51° Fahr.	St. Amand .....	Slate covering the coal formation	Near Valenciennes, Dep. du Nord	.....	28°	.....	.....
	Bourbonne les Bains	Granite, covered by Jura limestone	Nr. Chaumont, Dep. Haute Marne	.....	La Fontaine 80	2 springs 2,916	.....
	Luxeuil .....	Granite, covered with sandstone	Near Vesoul, Dep. de Haute Saone	.....	Grand Bain 75.5	8,640	.....
	Plombieres .....	Granite .....	Near Epinal, Dep. de Vosges	13	Ditto 95.75	9,000	.....
	Bains .....	Ditto .....	Near ditto, ditto	.....	Grosse Source 71	.....	.....
	Bagnoles .....	Ditto .....	Near Alençon, Dep. d'Orne	.....	28	.....	.....
France. From Lat. 47° to 40°. Long. 0° to 4°. Assumed mean temp. 56° Fahr.	Bourbonne l'Ar-chambault	Slate formation .....	Near Moulins, Dep. l'Allier	.....	Grand Puits 69	Grand Puits 86,400	.....
	Bourbon Lancy..	Ditto .....	Near ditto, ditto	.....	Ecures 84	10,800	.....
	Vichy .....	Coal formation, covering granite	Near Gannat, Dep. de l'Allier	.....	Bassin des Bains 57	9,360	.....
	Neris .....	Sandstone and coal, resting on granite	Nr. Montluçon, Dep. de l'Allier	.....	Puits de Cesar 89.5	19,800	.....
	Mont Dor.....	Trachyte .....	Near Clermont, Dep. de Puy de Dôme	34	Bains de Cesar 52 F.	12,780	Bains de Cesar 4,200
	Bourboule .....	Ditto .....	Ditto .....	28	65 F.	.....	.....
	St. Nectaire .....	Ditto .....	Ditto .....	.....	Gros Bouillon 45.75	.....	.....
	Chaudes Aigues.	Gneiss .....	Nr. Aurillac, Dep. de Cantal	.....	Par 118.0	307,188	No. 1 2 3

\* The mark (\*) indicates that the gas



*Springs.* (Continued.)

Gases evolved and their relative proportions one to the other.				Gaseous contents.		Solid contents.		
Carbonic acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to	
					Gr.			
				Sulphuretted hyd. ....		Sulphuret of sodium, sulphate of soda, and magnesia		
0 18	0 4.5	100 77.49	Longchamp. Athenas	.....	52	Muriates of soda and lime, sulphates of lime and magnesia	Athenas.	
						Muriates and sulphs. of soda, lime, and magnesia		
						Muriates and sulphs. of soda, magnesia, and lime	Vauquelin.	
						Muriates of soda, lime, and magnesia.		
*		*	Longchamp.	.....		Muriates of soda, magnesia, and lime.		
*		*	Longchamp.	Carbonic acid .....		Mur. soda, sulph. soda.		
				Ditto .....	13.478	Mur. of soda and potass, sulph. soda and lime	Puvis.	
100	0	0	Longchamp.	Ditto .....	Source des Celestins 62.	Carb., mur., and sulph. of soda	Longchamp.	
		100	Ditto .....			Carb., mur., and sulph. of soda.		
90.0	0.85	9.85	Daubeny ...	Carbonic acid .....	Source de la Made- laine 11.4	Carb., mur., and sulph. of soda	Bertrand.	
				Ditto .....	Source des Fièvres 18.2	Muriate of soda.		
				Ditto .....	2nd Spring 50.0	Carb., sulph., and mur. of soda	Bouillay and Henry.	
57 60 87	13 15 1	30 25 12	Daubeny ...	.....	Source de Par 14.5	Carb. and mur. of soda, magnesia, lime, and oxide of iron.	Chevallier.	

exists, but that its proportion is unknown.

## Catalogue of Thermal.

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours o	
						Water.	Gas.
France. From Lat. 47° to 44°. Long. 0° to 4°. Mean temp. 56° Fahr.	Chateau-neuf ...	Volcanic rocks .....	Con. with the chain of Central France	Near Gan- nat, Dep. de Puy de Dôme	Grand Bains 45.75°	.....	.....
	Evaux .....	Granite .....		Near Neris, Dep. de Creuse	Puits de Cesar 81.75	.....	.....
	Saint Laurent ...	Tertiary limestone, co- vering granite, with volcanic rocks near		Near Au- benas, Dep. d'Ar- deche	66	.....	.....
	Bagnoles .....	Ditto .....		Nr. Mende, Dep. de Lozere	57	6,192	.....
	Digne .....	Limestone in inclined strata .....		Dep. des Basses Alpes	Bassin de l'Etuve 59.25	.....	.....
France. From Lat. 44° to 42°. W. Long. 4° to E. Long. 4°. Assumed mean temp. 60° Fahr.	Greoulx .....	Limestone in inclined strata	Con. with the Alps of Dauphiny	Dep. des Hautes Alpes	41.75	.....	.....
	Aix .....	Jura limestone, disloca- ted and inclined		Dep. des Bouches du Rhone	Sextius 39.0	.....	.....
	Balaruc .....	Jura limestone, near the volcano of Agde		Nr. Cette, Dep. d'Herault	Varying from 66 to 52	.....	.....
	Sylvanes .....	Granite .....	Connected with the chain of the Pyrenees	Near St. Affrique, Dep. de l'Aveyron	48	.....	.....
	Rennes.....	Sandstone, breccia, and limestone, belonging to the coal formation, highly inclined		Near Li- moux, Depart. d'Aude	Bainfut 53.0	.....	.....
	Campagne .....	Ditto .....		Ditto .....	21.5	.....	.....
	St. Paul de Fe- nouilhades	From a fault in lime- stone, covering slate		Near Cau- dies, Dep. d'Aude	21.5	.....	.....
	Arles .....	Granite near its junction with limestone		9	Petit Escaldadou 85.3 F.	36,357	.....
	Preste .....	Granite .....		.....	Source d'Apollon 71.0	10,888	.....
	Vernet ..	Junction of granite with stratified rocks		17	Source interieur 72.2	2,455,668	.....
	Molitz .....	Granite .....		.....	Grande Source 40 3 springs 1,170	.....	.....
	Thucz .....	Granite and serpentine .		27	Source du Torrent Real 111.5	.....	.....
	St. Thomas .....	} Mica slate, resting on a quartzose granite		.....	No. 1..... 75	.....	.....
	Canavilles .....			.....	69.5	.....	.....

*Springs.* (Continued.)

Gases evolved and their relative proportions one to the other.				Gaseous contents.	Solid contents.		
Carbonic acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
				C.In.	Gr.		
				Carbonic acid.			
				Ditto		Carb., sulph., and mur. of soda.	
						Carb., mur., and sulph. of soda.	
						Mur. of magnesia and sulph. of lime.	
				Sulphur. hydr.....	14.3	Sulphate of magnesia and lime, mur. of soda.	
				Carbonic acid, sulph. hydrogen	25.32	Mur. of soda and magnesia.	
					1.5	Carb. of magnesia and lime, sulph. of lime	Robert.
				Carbonic acid 6.0		Mur. of soda and magnesia, and lime, carb. of lime	Figureir.
						Mur. and sulph. of soda and magnesia.	
} wholly				Carbonic acid	12.0	Oxide of iron.	
			Anglada	Nitrogen and oxygen	2.0	Sulphuret of sodium, soda, caustic and combined with sulphuric acid	Anglada.
			Ditto		0.978	Ditto	Ditto.
			Ditto		1.311	Ditto	Ditto.
			Ditto		1.326	Ditto	Ditto.
					0.984	Ditto	Ditto.



## Catalogue of Thermal

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours of	
						Water.	Gas.
France. N. Latitude 44° to 42°. W. Longitude 4° to E. Longitude 4°. Assumed mean temperature 60° Fahr.	Sorede .....	From granitic pebbles ..	Dep. des Pyrénées Orientales Arrond. de Ceret	.....	Font Agre 9°	.....	.....
	Reyneze .....	Mica slate .....		.....	Beu Calde 23·75	.....	.....
	Enn .....	Mica slate, resting on a saccharoid limestone		.....	62	.....	.....
	Thuez .....	Junction of granite with limestone along a line of fissure		.....	Source d'Exhalade 71	.....	.....
	Escaldas .....	Granite near its contact with slate		47	Buvette 47·1 F.	28,609	535
	Dorres .....	Like Escaldas .....	Valley of the Tech	48	44·4 F.	.....	.....
	Los .....	.....		.....	Source Gervais 24·25	.....	.....
	Ax .....	At the boundary line of granite and slate	Dep. d'Arriège, near Tarascon	25	Source des Canons 108·0	.....	.....
	Ussat .....	Limestone, with granite contiguous	Ditto, ditto	.....	40·0	18,000	.....
	Lez .....	Granite.....	Valley of	.....	Source A 26·4 F.	.....	.....
	Bagnères de Luchon	Granite near its junction with clay-slate	Dep. de Haute-Garonne	20	Grotte superieur 79·1 F. 77·75	.....	.....
	Encausse .....	Limestone .....	Dep. de Haute-Garonne, nr. St. Gaudens	.....	6·0	.....	.....
	Bagnères de Bigorre	Limestone resting on clay-slate, with patches of granite near it	Dep. des Hautes Pyrénées	20	Dauphin 59·0 F.	.....	.....
	Capvern .....	Limestone .....	Dep. des Hautes Pyrénées, near Bagnères de Bigorre	.....	15	.....	.....
	Barège .....	Clay-slates, with hornblende; granite not far distant	Dep. des Hautes Pyrénées	42	Grande Douche 51·9 F.	.....	.....
	St. Sauveur .....	Slaty limestone, with hornblende slates adjacent; granite not far distant	Ditto .....	25	La Houtalade 8·5 F.	.....	.....
	Cauterets .....	Clay-slate, with hornblende in nearly vertical beds, near the contact with granite	Ditto .....	31	Source des Œufs 70·1 F.	Source de Pauze alone 1,326 All the springs 12,240	Source de Pauze 61·8

## Springs. (Continued.)

Gases evolved and their relative proportions one to the other.				Gaseous contents.		Solid contents.	
acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
0	.....	.....	Anglada ...	Carbonic acid .....	Gr 6·8	Carb., sulph., and mur. of soda; <i>oxide of iron</i>	Anglada.
0	0	0	Ditto .....	.....	.....	Sulph. of lime and soda, mur. of soda	Ditto.
0	0	0	Ditto .....	.....	<i>Very small</i> .....	Ditto .....	Ditto.
0	0	0	Ditto .....	.....	.....	Ditto .....	Ditto.
0	0	100	Ditto .....	.....	1·02	Hydrosulphuret of soda, with soda and potass, caustic? sulph. of soda?	Ditto.
0	0	100	Ditto .....	.....	.....	Ditto .....	Ditto.
0	0	100	Ditto .....	.....	.....	Ditto .....	Ditto.
.....	.....	.....	.....	.....	.....	Hydrosulphuret of sodium, caustic soda.	.....
.....	.....	.....	.....	.....	.....	Sulph. and mur. of mag.	.....
.....	.....	.....	.....	.....	2·2	Sulphuret of sodium, carb., sulphate, mur. of soda.	.....
.....	.....	.....	.....	Carbonic acid .....	.....	Sulph. of lime, magnesia, and soda.	.....
.....	.....	.....	.....	Ditto .....	Source de la Reine 1·37	Sulph. of lime, magnesia, and soda, mur. of magnesia and soda	Gauderex.
.....	.....	.....	.....	Ditto .....	8·0	Sulph. of lime and mag.	Save.
0	0	100	Longchamp.....	.....	2·3	Sulphuret of sodium, caustic soda, sulph. of soda.	.....
.....	.....	.....	.....	.....	1·1	Ditto.	.....
0	0	100	Longchamp.....	.....	Le Pré 29.	.....	.....

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic f evolved in 24 hour	
						Water.	Gas
<i>France.</i> N. Lat. 44° to 42°. W. Long. 4° to E. Long. 4°. Assumed mean temp. 60° Fahr.	Eaux Bonnes ...	In a valley of disruption, from highly inclined beds of limestone, near its contact with granite	Connected with the chain of the Pyrenees	Dep. des Basses Pyrénées	26	Source Vieille 32° 0 31° 4 F.	.....
	Eaux Chaudes ...	In a valley of disruption, at the junction of granite, with inclined beds of limestone		Ditto .....	22	Clot 34° 6 F.	3,924 .....
	Cambo .....	Clay-slate in inclined strata, resting on granite		Ditto .....	.....	10.	.....
	Dax .....	Compact limestone, with trap near it		Dep. des Landes	.....	82° 25	.....
	Barboutan .....	Tertiary ? .....		Dep. de Gers	.....	44.	.....
	Castéra-vivante ...	Tertiary ? .....		Ditto .....	.....	25	.....
<i>Switzerland.</i> N. Lat. 48° to 46°. E. Long. 6° to 10°. Assumed mean temp. 49°.	Pfeffers .....	Disrupted beds of limestone	Canton of St. Gall	23	From 50° 5 to 51° 0 48° 9 F.	Very variable, greatest in summer (=429,120), least in winter	.....
	Vals .....	Clay slate and compact limestone	Valley of Lugnitz, canton of Grisons	.....	14	.....	.....
	Weissenburg .....	.....	Canton of Berne	27	32° 5 F.	1,423	.....
	Loueche .....	Disrupted beds of limestone, with granite not far distant	Canton of Valais	47	74° 1 F.	161,364	.....
	Baden .....	.....	Canton of Argau	10	St. Verene 78° 0	One spring 186,325	.....
	Schinz nach .....	.....	Ditto .....	10	39° 25	.....	.....
	Yverdun .....	.....	Canton of Neuchâtel	13	varying a degree or so 27	.....	.....



*Springs.* (Continued.)

Gases evolved and their relative proportions one to the other.				Gaseous contents.		Solid contents.	
Carbonic acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
				C.In.	Grs.		
					0.949	Sulphuret of sodium, caustic soda, sulph. of lime.	
					6.000	Sulph. of magnesia, mur. of soda and magnesia	Poumier.
					1.5	Sulph. and mur. of mag.	
				Sulphuretted hyd.			
				Ditto		Sulph. of soda and mur. of lime.	
					2.61	Sulphate of soda and magnesia, muriate of soda and magnesia	Capeller.
					17.3	Sulph. of lime and soda, carbonate of lime	Ditto.
				Carbonic acid	21.1	Sulphates of lime, soda, and magnesia	Brunner.
0	0	100	Ure	Ditto	21.47	Sulphate of lime, magnesia, and soda	Morell.
				Ditto	2.56	Sulph. of lime, muriate of soda and mag., sulph. of soda	Bauhoff.
				Sulphuretted hyd.			
				Ditto	6.0	Sulphate of lime and soda, mur. of soda and mag., oxide of iron	Ditto.
				Carbonic acid	2.3		
					0.983	Muriate of soda, sulph. of lime, carb. of soda	Morell.

## Catalogue of Thermae

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic f evolved in 24 hours	
						Water.	Gas.
<i>Savoy.</i> N. Lat. 46° to 70°. E. Long. 6° to 7°. Assumed mean temp. 50°.	St. Gervais	Talc slate.....	Near Sallenche	17	56·50°	1,440	.....
	St. Martino .....	Gritty dark-coloured sandstone	Near Worms, in the canton of Valtelline	50	Varies from 68 to 46	.....	.....
	Aix .....	.....	Near Chambery	.....	67·0	.....	.....
	Bonneval .....	.....	Tarantaise, nr. BurgSt. Maurice	.....	.....	.....	.....
	La Perrier .....	.....	Near Moutiers, Tarantaise	14	49·5	.....	.....
	Moutiers .....	.....	Tarantaise .....	.....	47·25	.....	.....
	Echaillon .....	.....	Maurienne .....	.....	39·6	.....	.....
	Courmayeur .....	.....	Valley of Aoste	.....	14·5	.....	.....
	St. Didier.....	.....	Vallée d'Aoste	.....	20·25	.....	.....

*Italy.*

N. Lat. 45° to 43°. Mean temp. 60°.

<i>Piedmont</i> ...	Acqui, excess of temperature	°
	Acqua della Bollente .....	107· F.
	Valdieri .....	86·75
	Vinadio .....	93·50
	Craveggia .....	21·50
	Bobbio.....	.....
	Acqua Santa, near Genoa ...	17·
	La Penna, near Voltri .....	17.
	Roccabigliera, near Nizza...	21·5
<i>Lombardy</i> ...	Abano, near Padua.....	121·0
<i>Tuscany</i> ....	Lucca .....	64·
	Monte Cerboli.....	50·
	Pisa .....	46·
	Monte Catini .....	22·*
<i>Papal States</i> ...	Nocera.....	.....

*Italy.*

N. Lat. 43° to 40°. Mean temp. assumed to be 60°.

Bagni de San Filippo .....	49·
Bagni de Vignone (the Reservoir).....	.....
Viterbo, Bullicami (the Lake) .....	19·
Civita Vecchia .....	25·
Civillina .....	.....
Puzzioli, Temple of Serapis .....	37·5
Baths of Nero .....	121·2
Pisciarelli.....	51·0
Torre del Annunziata.....	26·

\* At the Reservoir evolves gas consisting

*Springs. (Continued.)*

Gases evolved and their relative proportions one to the other.				Gaseous contents.	Solid contents.		
Carbonic acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
.....	.....	chiefly	Daubeny ...	Carbonic acid .....	Grs. 45·47	Sulphate of soda and lime, mur. of soda and mag.	Pictet.
.....	.....	.....	.....	.....	33·3	Sulphate of soda and lime, carb. of lime and mag.	Demagre.
0	0	100	Gimbernati	Carbonic acid, sulph. hydrogen	Sulphur spring 4·0	Sulphate of lime, soda, and mag., muriate mag. and soda	Thibaud.
12	0	88	Daubeny.	.....	.....	.....	.....
10	0	90	Socquet ...	Carbonic acid, sulph. hydrogen, trace	58·1	Sulphate of lime, soda, and mag., mur. of mag. A strong brine spring.	Socquet.
.....	.....	.....	Daubeny ...	Carbonic acid .....	.....	Mur. soda and mag., sulph. of lime and alumina, oxide of iron	Ruffinelli.
.....	.....	.....	Ditto .....	Ditto .....	.....	Mur. soda, sulph. of mag. and lime, oxide of iron	Ditto.

Islands connected geographically with Italy, and in the same latitude, viz. :

N. Lat. 43° to 40°. Mean temp. 61°.

Trapani, <i>Ischia</i> , varies from 83°·5 to 94°·5...	88° F.
Aqua de Cappone, <i>Ischia</i> .....	27·25
Almitello .....	44·00
Alghero .....	62·00
Bagno di Ischia .....	52·00
Capo Restituta .....	62·00
Capo Ferro, <i>Sardinia</i> .....	98·
Aqua Cotta .....	44·
Castelluccio .....	39·
Castelluccio .....	50·
Castelluccio, <i>Corsica</i> .....	61·
Castelluccio .....	57·

Italy and adjacent islands.

N. Lat. 40° to 37°. E. Long. 13° to 19°.

Assumed mean temp. 63°.

Santa Eufemia, in <i>Calabria</i> .....	0
Bagno di Lipari, <i>Island of Lipari</i> .....	.....
Termini, <i>Sicily</i> .....	47·
Trepani, sulphureous, hot .....	.....
Sciaccia, Baths of Santa Cologero .....	63·

of 10 carbonic, 2 oxygen, 98 nitrogen. (Daubeny.)



*Spanish Peninsula.*

N. Lat.  $41^{\circ}$  to  $36^{\circ}$ . W. Long.  $9^{\circ}$  to E. Long  $1^{\circ}$ .

Mean temp. not sufficiently ascertained.

*In Spain* . . . Along the line of the Pyrenees are several, especially in Catalonia, near Barcelona; and at Albama, near Catalayud in Aragon.

Near the volcanic hills of Murcia—Fuente de Buzot, near Alicant ( $104^{\circ}$  F.), and Archena, near Mureia.

At the foot of the Sierra Noveda range—that near Merida, in Estremadura.

Amongst the mountains of Grenada—the baths of Javal-Cohol, near Baeza; those near Alhama; and those near Almeria.

Amongst the mountain-chain of the Basque provinces—Calda di Bonar, near Leon; and Orense, in Galicia.

*In Portugal.* . *Province of Minho*—San Antonio das Taipas, or Caldas das Taipas, near Guimarens, sulphureous  $91^{\circ}$  F.; 2. Caldellas de Rendusa,  $89^{\circ}$ ; 3. Canaveres, near Guimarens, sulphureous,  $93^{\circ}\cdot 2$ ; 4. Guimarens, sulphureous,  $138^{\circ}$ ; 5. Monção, near Ueana,  $109^{\circ}\cdot 4$ .

*Province of Tra los Montes*—1. Carlao, Villa-real, sulphureous,  $92^{\circ}\cdot 8$ ; 2. Chaves, near Braganza, alkaline,  $141^{\circ}\cdot 8$ ; 3. Pombal d'Anicaes, near Torre de Moncorvo, sulphureous,  $95^{\circ}$ ; 4. Ponte de Cavez, Villa-Real, sulphureous,  $74^{\circ}\cdot 75$ ; 5. Rede de Corvaceira, de Moledo, de Panaguião,  $98^{\circ}\cdot 6$ .

*Province of Beira*—1. Alcafache, near Viseu,  $98^{\circ}\cdot 6$ ; 2. Aregos, near Lamego,  $142^{\circ}\cdot 25$ ; 3. Canas de Senhorim, near Viseu,  $93^{\circ}\cdot 2$ ; 4. Carvalhal, near Viseu,  $98^{\circ}\cdot 6$ ; 5. Santa Gemil, or Lagiosa, near Viseu,  $120^{\circ}\cdot 2$ ; 6. San Pedro Dosul, near Viseu,  $153^{\circ}\cdot 5$ ; 7. Penagarcia, or Caldas di Monsortinho, near Castelbranco,  $68^{\circ}$ ; 8. Penamacon,  $68^{\circ}$ ; 9. Prunto, Azenha, or Vinha da Rainha, near Coimbra,  $89^{\circ}\cdot 6$ ; 10. Ranhados, near Pinhel,  $107^{\circ}\cdot 6$ ; 11. Rapoila de Coa, near Castelbranco,  $93^{\circ}\cdot 2$ ; 12. Unhaes da Serra, near Guarda,  $87^{\circ}\cdot 8$ .

N.B. All the above are sulphureous, excepting Penamaçon.

*Province of Estremadura*—1. Caldas da Rainhas, near Alemquer, sulphureous,  $93^{\circ}\cdot 2$ ; 2. Cascaes, or Estoril, Torres Vedras,  $84^{\circ}\cdot 2$ ; 3. Gaieiras, near Alemquer, sulphureous,  $91^{\circ}\cdot 4$ ; 4. Leyria,  $77^{\circ}$ ; 5. Lisbon, sulphureous,  $86^{\circ}$ ; 6. Miorga, Alcobaça,  $82^{\circ}\cdot 4$ ; 7. Povea de Coz, Alcobaco,  $77^{\circ}$ ; 8. Rio-Real, Alemquer, sulphureous,  $75^{\circ}\cdot 2$ ; 9. Torres Vedras,  $111^{\circ}\cdot 2$ ; 10. Agua santa de Vimeiro,  $78^{\circ}\cdot 8$ .

*Province of Alentijo*—1. Cabeço de Vide,  $80^{\circ}\cdot 6$ .

*Province of Algarves*—1. Monchique, near Lagos, sulphureous,  $92^{\circ}\cdot 7$ ; 2. Tavira,  $75^{\circ}\cdot 50$ .

*Provinces of European Turkey.*

N. Lat.  $46^{\circ}$  to  $41^{\circ}$ . E. Long.  $17^{\circ}$  to  $29^{\circ}$ .

Mean temp. not sufficiently ascertained.

Line of thermal waters extends from north to south in Servia, at the foot of the chain of mountains which connects the Carpathians with the ridge of the Balkan, and through which the Danube forces its way between Moldava and Gladova. The line of hot springs begins at Mehadia, in the Bannat, and extends south beyond Nizza in Servia.

A second line may be traced running east and west at the foot of the Balkan. The hottest has a temperature of  $162^{\circ}5$ .

A third group exists in southern Macedonia, near Salonichi and Serres. They are mostly sulphureous.

*Greece and its Islands.*

N. Lat.  $41^{\circ}$  to  $36^{\circ}$ . E. Long.  $20^{\circ}$  to  $27^{\circ}$ .

Mean temp. not ascertained.

A group of thermal springs at the base of Mount Olympus, of which that at the Pass of Thermopylæ is the only one whose temperature is ascertained. This found by Clark to be  $113^{\circ}$ .

Hot bath of Venus, east of Corinth.

Korantzia, south of Mount Geranicus, near the Gulf of Corinth, gaseous eruptions and a spring at  $87^{\circ}8$ .

At Venetiko, west of Lepanto, a sulphureous thermal spring, called Taphoi (Tombs of Nessus).

Six leagues from Patras, a saline thermal spring,  $96^{\circ}8$ .

In the Morea, near Methone, in the ancient Argolis, near the base of an extinct volcano, and in the Archipelago, in the islands of Negropont, (Lelantho, near the ancient Chalcis,) Milo, Thermia, and Lemnos, are thermal waters\*.

*Iceland.*

N. Lat.  $63^{\circ}$  to  $67^{\circ}$ . W. Long.  $12^{\circ}$  to  $25^{\circ}$ .

Mean. temp.  $37^{\circ}4$  Fahr.

A very numerous class of sulphureous waters, with a high temperature, in that part of the island, where trachyte exists, and volcanic eruptions at present take place.

A second class of thermal waters of a lower temperature, and impregnated only with carbonic acid gas, in the volcanic promontory of Sneefield-Syssel, where igneous operations have ceased†.

\* Consult Virlet, *Expedition Scientifique de Morée*.

† See Krug von Nidda in *Edinb. New Phil. Journ.*, vol. xxii.

